A Study of Land Transformation in Savar Upazila, Bangladesh, 1951-2001:

An integrated approach using remote sensing, census, map and field data

Md. Shahedur Rashid
B.Sc., M.Sc. (Jahangirnagar), M.A. (Durham)

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Declaration

The work contained in this thesis is entirely that of author. Material from the published work of others, which is referred to in this thesis, is credited to the author(s) in the text. No part of this work has been submitted for any other degree in this or any other university.

The main body of text (excluding references and appendices) is approximately 110,000 words in length.

(Md. Shahedur Rashid)

ABSTRACT

The aim of this research is to analyse the process of land transformation for an upazila (subdistrict) of Dhaka, the Capital of Bangladesh, using image interpretation techniques and GIS approaches. The analysis spans a time period at decennial intervals from 1951 (predevelopment phase) to 2001 (urbanisation stage). The upazila is considered in Bangladesh to be the main focal point of government planning, land management, environment and development policies. Savar Upazila has been selected as the study area because of its rapidly changing population density, socio-economic phenomena and land use/cover change since the independence from the Great Britain.

The major sources of high resolution (up to a 2.4 metre resolution) remotely sensed data are panchromatic and infrared aerial photography (1953, 1984 and 1990); CORONA KH4 and KH4b spy satellite panoramic film (1962 and 1972) and IRS-1D panchromatic imagery (2000); and DGPS based GCP coordinates of 2001. Digitally converted conventional and Historical administrative, settlement, planning, revenue and topographic maps have been digitised and used at a large-scale of up to 1:3,960. Moreover, the enhanced 1951, 1961, 1974, 1981, 1991 and 2001 population censuses are used in parallel to help interpret images and related factors. In-depth survey and participatory approaches were used during the fieldwork at plot level to help interpret and develop a weighted land cover model and to understand factors responsible for change. In grid format, compatible to temporal image data, detailed land value data were converted into gridded format compatible with a decadal time-series of imagery and from the field for the early 1950s to 2001 integrated with mauza maps. The attribute data have been used as if it was an image data layer in order to visualise land value data.

The results illustrate that significant and visible land transformations and population change have occurred over the last half-century from a completely river-dependent countryside to a modern road network orientation, with a change from the *byde* (low-lying flood-prone area) to *chala* (highland flood-free area) land economies. A spatio-temporal land transformation index is proposed to explain the complex micro-scale change that have taken place using land use and land value data. Remotely sensed data provides the context with which to interpret past and present land cover and land use. This study shows the importance of modern GIS techniques to integrate enhanced field and secondary data/maps with raster data as well as for mapping historical images and information on the future development, land reform/management, environmental study and planning in Bangladesh.

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I would feel debt free if this research could play meaningful role for the intellectual communities and for the betterment of ordinary people.

(M. S. Rashid)

DEDICATIONS

To my beloved MOTHER
and the departed soul of my FATHER

and

For the Peaceful Use of
Remote Sensing for All Mankind

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CHAPTER 1: INTRODUCTION

1.1.0. Introduction

Land transformation is inevitable in a zone at the dynamic rural-urban interface in the periphery of any big city such as Dhaka. A study of land transformation helps to evaluate how a rural land use may gradually convert to an urban use. Base line historical data and remotely sensed images help to identify the complex characteristics and the context of changes of land cover and land use. Without knowing the complexities and context of change, it is difficult to achieve effective planning, land management, and environmental monitoring.

The primary focus of this research is to examine the applicability of Geographical Information Systems (GIS) and Remote Sensing (RS) technologies for the identification of population and land cover/use change as part of the process of sustainable development, resource management and development planning in a sub-district (upazila) of the capital Dhaka in Bangladesh (Figure 1-1). The upazila, with its further administrative area subdivisions of union and then mauza, is considered in Bangladesh as the focal point of local government, land use planning, environment and development policies.

In fact, Savar upazila was untouched by any infrastructural development until the 1950s and was under a complete agro-based rural system in a traditional predevelopment phase. In the early 1960s, the first development was triggered by construction of the national highway and a significant amount of land was acquired by the government for the infrastructural developments in the heartland of the upazila. Since then there has been a gradual evolution towards urbanisation. Interestingly, the entire process of change since the predevelopment period of the early 1950s was recorded and imaged at a high spatial resolution by remote sensing at specific temporal intervals. The acquisition of these images fits well with the decennial population census data and gives a unique opportunity to see land transformation from the both human and physical perspectives.

For understanding the in-depth nature of transformation systems census data, aerial photos, satellite images conventional maps, and field work are the major sources of data. Based on union (sub-administrative unit of an upazila) and plot (a land ownership unit) data, various aspects of land transformations are studied in the context of environmentally sustainable local-resource management and development at the *upazila* (sub-district) level (known as the micro level planning zone). The approach taken will facilitate the integration of local development with the national level planning process, which has not been possible hitherto.

Savar, a western upazila of Dhaka District and also a peri-urban area of the capital city of Bangladesh (Figure 1-2), has complex landforms. It has been selected as the study area due to its ideal conditions which will be discussed later. An upazila is the country's third administrative order after the division and district, and is considered in Bangladesh as the focal point of government's local elected and appointed administrations and the base-area for implementing planning, environment and development policies. Table 1-1 gives summary of the administrative orders in Bangladesh.

At present, there are more than fifty years of census data, maps and images relating to the upazila's population, land ownership, transport, physiography, agriculture and so on. Satellite remote sensing (RS) data and aerial photographs are also available over the same period. Despite the availability of a wide range of raw vector and raster data at the local

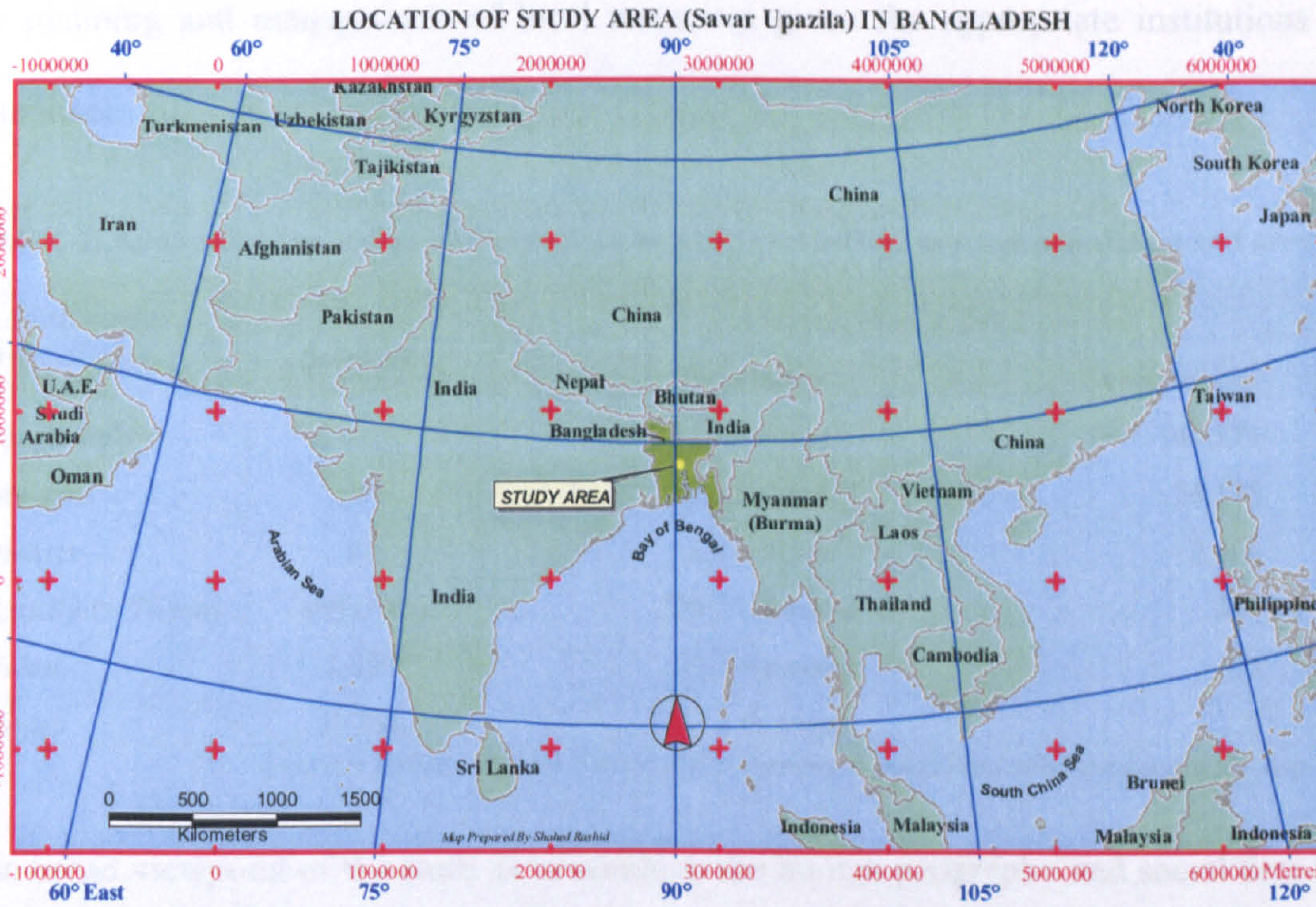


Figure 1-1 The above map shows the location of the study area known as Savar upazila (yellow colour) in the centre of Bangladesh and as a part of the Asia (light green colour). Bangladesh is mostly surrounded by India with a small exception in the southeast, where it has a 141 km long common boundary with Burma. The Bay of Bengal is situated in the south. Nepal and Bhutan, landlocked countries, are only few kilometres away (through Indian territory) from the Bangladeshi northern-most border.

upazila administrative and field levels, there is a lack of trained manpower for using those census data and remotely sensed images and so meaningful analysis for development and planning purposes cannot at present be undertaken by local officials. On the other hand, the complexity of some databases, especially those involving the integration of regional, national and local levels, is such that work has been painfully slow and has eventually been limited to the visual analysis of the simple spatial distribution of certain parameters of land cover. That is why appropriate data handling technologies like remote sensing and GIS could provide an excellent test case for exemplifying how data could be best utilised for planning and management of local resources given the appropriate institutions and personnel.

Table 1-1: Administrative orders of Bangladesh and their respective average population and area size.

Administrative Order/Units	Total Subunits	Average Size in 2001	
		Population	Area in km^2
Bangladesh	-	123.1 million	147,571
Division	6	20.5 million	24,595
District	64	1.9 million	2,306
Upazila (+ *Thana)*	460 (+36)	228.1 thousand	298
Union	4,451	27.7 thousand	33
Mauza	59,990	2.1 thousand	2

Source: Calculated from Census 2001: Primary Report (The Daily Janakantha, 24-Aug-2001)

The broad viewpoint of the study is to combine the human geography and social data with space and air-borne photographs, that is, in the terminology of Rindfuss and Stern (1998) by integrating *people* with *pixels*: *census* and *remote sensing* data. One of the ultimate intentions of this research is to establish the applicability of GIS and Image Analysis Systems (IAS) technologies using census and satellite data. The factors affecting land cover/use changes will be identified and mapped over a period of fifty years in a peri-urban area of Dhaka. A standard interpretation technique will then be developed with several specific guidelines.

The study emphasises the benefits of using GIS and remote sensing in an integrated way. It shows how an array of data bases and tools for handling different sectoral data, maps, and remotely sensed images can help to reveal the complexities of land transformation and can be used to validate existing records, i.e. from the vertical (space satellite) to historical (census reports) to horizontal (field-data) viewpoints.

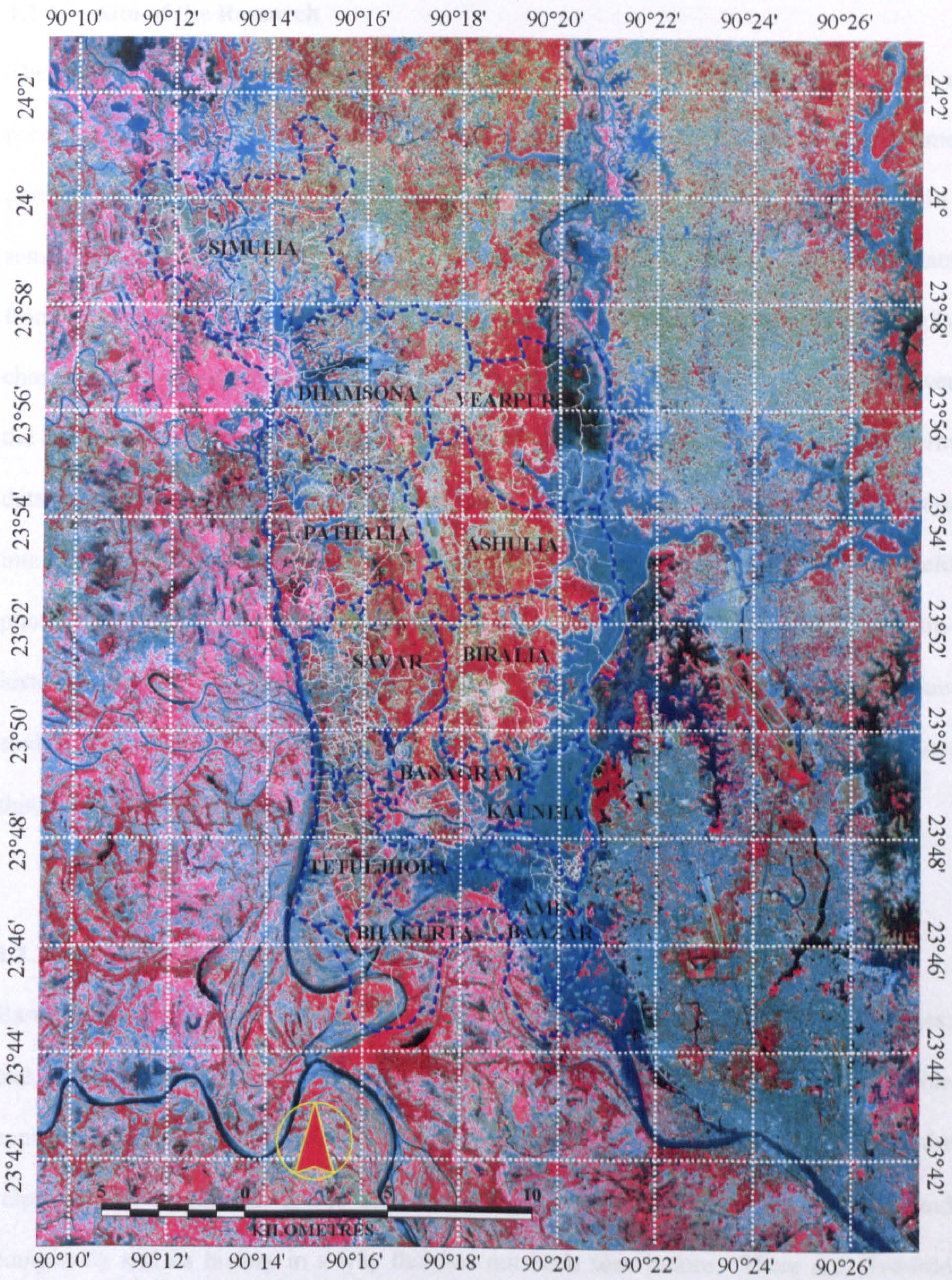


Figure 1-2 Savar upazila and its sub-administrative Unions on the 16m resolution ADEOS-AVNIR (Bands 2-4, December 10, 1996). With complex landforms, the brighter reflectance shows lower moisture content (e.g. sandy and exposed soils), red colour highlights vegetation cover, while the darker part shows higher content (e.g., water bodies and rivers). The lower right corner (outside the upazila) of the image is the central part of the capital city, Dhaka.

1.1.1. Aim of the Research

The aim of this research project is to detect and analyse land transformation from a predevelopment rural system to an urbanization phase at decennial intervals over a time period from 1951 to 2001 in Savar upazila (sub-district) of Dhaka using integrated multi-sensoral remotely sensed images and, in parallel, decennial population census and data from field survey. Savar has been selected as the study area because of its rapidly changing population density, physio-social phenomena and land –use /-cover change over the last few decades, and also because of the availability of variety of sources of long-term data (e.g. census data), contextual information, maps (mauza map) and imagery from international (e.g satellite images) to national (e.g. aerial photos) to field levels (e.g. field photos). The 50 year duration of the study-period will help us to understand the spatio-historical detail of the past which may help to predict the future. There are only a few studies where social data have been fully integrated with the remote sensing techniques; this research is intended to further explore the potential of the approach.

1.1.2. Specific Objectives to Achieve

Based on the primary aim, the objectives of the research fall into two broad categories: one, ***methodological*** which can be used for this study and perhaps for the wider academic community; and two, a ***practical perspective*** for Bangladesh, which may be used by the 'elected' and 'appointed' policy and decision makers for understanding in-depth land complexity and its history in a way that has not been seen before. There are, five-fold main objectives (subdivided into methodological and practical):

(a) To collect and develop databases and RS images of land transformation systems

- **General Objective:** To find the most suitable sources of primary and secondary databases and datasets for the study of land transformation between 1951 and 2001. To compare their 'temporal and spatial resolutions'. To convert data into digital format including geo-correction and transformation at an appropriate accuracy.

- **Practical Goal:** To collect, scan, digitise and evaluate data/maps/images from various government and private sources based on unique projection parameters and compatible data entry approaches. To develop skills for a range of GIS and image processing software in order to manage and analyse large databases and images and, where necessary, compare and assess the quality pre-existing datasets available from a variety of sources and the datasets newly developed for this research. Also, to employ state-of-the-art GPS technology, and to give guidance on how the developed database may help in the development and planning process of Bangladesh.

(b) To contextualise and interpret the process of land transformation

- **General Objective:** To develop a feature-specific 'image interpretation technique' for high resolution remotely sensed imagery to contextualise the land transformation process on a portion of unexplored, rapidly changing terrain of Bangladesh at the decennial scale between 1951 and 2001.

- **Practical Goal:** To apply the methods of interpretation to maps and contextualise the land and water feature-specific detail of land transformation history and the cumulative decennial changes as depicted on the images, including some new elements of interpretation appropriate for the study of land use.

(c) To enhance population change data using interpretation of imagery

- **General Objective:** To find out the 'enhancement, analysis, data attribute development, ungeocoded to geocoded coverages and assessment techniques' of population census data with the help of the above ***(b)*** interpreted remote sensing images; also to establish a significant link between historical census data and the long term remote sensing images using GIS approaches.

- **Practical Goal:** To apply the above procedures at the lowest census tract or administrative unit in order to enhance the spatial scale from the smallest and traditional Enumeration District (ED) to Sub-EDs and to find out the complementary roles of remote sensing including factors involved in the land transformation system.

(d) To develop a spatio-temporal transformation index

- **General Objective:** To introduce and formulate 'an indexing means based on an integrated census and remote sensing metadata' for quantifying the weight of a spatio-temporal transformation (ST) index and its potential usages at different phases of development by establishing a significant link between historical census data with the long term parallel remote sensing images.

- **Practical Goal:** To rank the sub-administrative units of the study area using the ST Index and explain the advantages and disadvantages of the various ranking methods with appropriate examples for the predevelopment, developing and pro-development phases of the land transformation rate.

(e) To assess the social impact of land transformation at the plot level

- **General Objective:** To assess the ability of local villagers to interpret high resolution satellite images like CORONA and to visualise and make comparisons of the 'impact of land transformation on geo-social values' during 1951-2001 by pixelising field data using high resolution imageries and a suitable plot level equivalent polygon-coverage.

- **Practical Goal:** To map 'georeferenced social data' and to collect field photos at the plot level of the mauza (broadly village) map to understand the dynamic of 'weighted land use' over time and to identify the factors for centres of gravity and space using appropriate techniques including GPS survey and land price data collection and entry.

The above objectives generally will be reflected in the forthcoming chapters respectively based on the specific themes above but they may also be discuss more than one chapter as appropriate. The study is designed carefully and in a unique form as follows:

(1) Handling a large amounts of data and images (hundreds of Gigabytes) in order to perform this research and acquisition of the skill to use them altogether in order to pursue the aim of integration.

(2) Unique opportunity of availability of Parallel Census and remote sensing images since 1950s. No such studies have been carried out before.

(3) First intensive use in Bangladesh of the CORONA Spy Films for a land transformation study analysed with the Commercial Satellite of Indian Remote Sensing (IRS-1D) and Aerial Photos.

(4) Practical application of census and remote data in an integrated form with the use of image processing and GIS approaches.

(5) How to integrate large scale maps with the high-resolution images in some novel ways.

(6) Extensive use of field experience, photographic evidence and people's opinions, coordinated in a new dimension of the study.

(7) Difficulties highlighted in handling datasets of and in Bangladesh as and where apposite.

(8) A combined use of multi-sourced data and multi-sensoral images for achieving a common target.

(9) Encourage social scientists to work with remote sensing data without knowing complex algorithms and how a remote sensing expert can help to interpret social data like population censuses as the field is relatively new.

(10) Use of visualisation techniques for weighted land use has been introduced for the first time in this long term transformation study.

1.1.3. Research Questions

To accomplish the above objectives, it is important to focus on some of the basic issues. These are mainly:

(1) What are the available sources of data and images for the study? Are they compatible? Is it possible to use them in a single platform to achieve the aim? What would be the best resolution of imageries where census data are also concerned?

(2) What are the imageries suitable for the study of land transformation? Is it possible to get decennial remotely sensed images? How can past images help to interpret the current land features and its changes?

(3) How can we integrate remote sensing images with population census data? How can remote sensing help to generate a better resolution census map?

(4) Is it possible to quantify the land transformation? How can we judge which land has had faster change than others?

(5) Are there any ways to assess the impact of land transformation at a micro scale? Can we apply a participatory approach to understand remotely sensed data? How can a map help to integrate any social parameter to visualise the gravity of change over time? Can we measure the change of the centre of gravity and can we see social data as like a band of an RS image to explain the changing centre of gravity?

In order to get the appropriate responses of the above queries, a very carefully plan was followed where time and budget were the main constraints.

1.1.4. Tasks to be Involved for Achieving Targets of Research

To achieve the above aim, objectives and research queries, the following steps will be required as a part of the integrated approach of the thesis:

(1) As Bangladesh is a less developed country, there is almost no data readily available for higher quality research work, particularly where the state-of-the-art technologies like GIS and remote sensing are concerned. So I needed to develop appropriate databases which are very time-consuming and complicated and require careful planning and skill prior to start of the fieldwork and analysis. Moreover, what form of data is available, and the quality of them is not always easy to discover. My major work involved here:

(a) Developing GIS databases and capturing population data from the census reports of 1951, 1961, 1974, 1981, 1991, and 2001 in a GIS format. For collecting the census data of 2001 from the field, my work had to be organised in such a way so that I could be in Savar in January 2001 when the census was in progress.

(b) Develop an administrative boundary upazila dataset, digitise mauza maps at plot level, plan attribute tables for each coverage to be collected from censuses, images and from the fieldwork, so that census and social data can be integrated. I also needed a GPS survey for the major landmarks and features like ponds and roads and to locate union and mauza boundaries and plot (Daag) numbers (depending on the availability of data) based on the lowest administrative units using DLRS (Directorate of Land Records and Surveying) and LGED (Local Government Engineering Department) maps.

(c) Collect Hard Copies Aerial Photos of 1953, 1984 and 1990. This was a difficult one as the AP are not allowed to be taken abroad or kept in personal possession. Find out the relevant CORONA Films using the internet site of USGS and digitise them with the highest quality possible scanner and transform them into a digital format. All of the images should be digitally geo-corrected and geo-referenced with sufficient GCP (Ground Control Points) based on DGPS surveying.

(2) To interpret a panchromatic image requires an extensive theoretical skill as well as field experience in order to interpret the Aerial Photos including B/W and Infrared, untested CORONA films and uncommon use of IRS-1D. Firstly we need to find out the major physical features and then verify them on the ground. Once identified, each feature should be linked with its own historical events, which may have changed the landscape over the last 50 years. Moreover, there is a need to talk to the local people about the backgrounds and context of seasonal and historical land use dynamics.

(3) Population census data and the settlements on the images have direct links. I need to identify the various classes of settlements, their pattern of distribution with respect to local land types and the physical direction of growth. Also I need to mark clearly the extent of settlements in order to enhance the mauza-level census data at a sub-mauza scale.

(4) Calculation and analysis of the by-products of the census and images based on the tabular primary data and try to link vector and raster data for searching a suitable formula so that I can quantify the land transformation rate.

(5) Carry out a detailed plot level survey of a few villages using mauza level plot maps and try to assess the impact of change over time. In this regard, I will use stepwise participatory remote sensing approach and collect opinions of the local villagers. Though this is a huge task, it will help to understand the reasons behind the change and to identify the forces relating to the land use change.

So, the main objectives of the study are to identify and analyse land transformation due to the decadal (i.e. 1951, 1961, 1974, 1981, 1991, and 2001) population growth in Savar upazila based on available multi-sensoral and multi-temporal remote sensing images using change detection techniques, and the integrating of the outcome with advanced GIS approaches. Appropriate methods will be developed to co-ordinate between the technology (GIS and RS) and information (Census and Maps) media. In this field of research very high resolution US CORONA intelligence satellite images of 1962 and 1972 will be used and their role will be considered as one of the significant aims of the study. These photo quality and cheaply available CORONA images may also help to develop a participatory remote sensing concept which is a completely new idea in this field of research in Bangladesh.

1.2.0. Basis of the Study: Censuses and Satellites in an Integrated GIS Format

The foundation of this research draws upon the several thoughts and guidelines of various authors, Rindfuss and Stern (1998) are remarkable amongst them. It is relevant to quote a few paras from their paper (emphasis is added to indicate the importance for the current research):

> "There is increased interest in making scientific progress through the **use of remotely sensed data in social science research,** ...(though)... remotely sensed data have not been a popular source of social science research. ...(because)... social scientists are likely to be sceptical that remote sensing can measure anything considered important in their fields of study. A related issue is that social science is generally more concerned with why things happen that where they happen (Turner, in press). Many social scientists do not know what a pixel is and ...there is a specialised language that those in the remote sensing area know and use, and outsiders do not understand. Similarly, an average remote sensing expert is

unlikely to be conversant with a wide range of social science problems and solutions.

> ...Remote sensing is expensive and government spending on it is more justifiable if it improves our understanding of the social systems by being incorporated into social science research. In addition, the contribution of social scientists might allow remote sensing experts to 'see' landscape features in the remotely sensed data not previously apparent. Another consideration involves the growing interdisciplinary community of scientists interested in ... related issues of human-environment interaction who need to compare data on social and environmental phenomena at the **same spatial and temporal scales**. For them, fusing social and remotely sensed data should be an attractive strategy.
>
> Remote sensing proved an additional means of **'contextual data'** and has the potential to supplement georeferenced social data by characterising numerous aspects of the context, ranging from land cover ...to weather. ...Models that combine remote observation with ground based social data have the potential to improve understanding of the determinants of various **land-use changes**.
>
> Linking remote sensing with social science presents special challenges for data systems. A straightforward but significant problem is to provide **georeferencing** for social data as to link them to remotely sensed data, which are normally **geocoded**. ...(Therefore,) the question **is whether the parallel social data are available in the forms of that are compatible.** (However,) researchers ... face the problem of finding **appropriate social data for to match with remotely sensed data**, or vice versa."

It is also argued that remote sensing techniques may provide population estimates that approach the accuracy of traditional census methods if sufficiently accurate in situ data are available to calibrate the remote sensing model. Unfortunately, ground-based population estimation may be inaccurate (Clayton and Estes, 1979). In many instances in developing countries, remote sensing methods may be superior to ground-based methods (Jensen and Cowen, 1999).

Geoghegan *et al.* (1998) suggested that to socialise the pixel is to take remote sensing imagery beyond its use in applied science and towards applications in addressing the concerns of the social sciences. Two avenues of research of this kind offer the potential to shed light on land use and land cover change using census data: mining the pixel and modelling from the pixel. Mining the pixel involves seeking social meaning in imagery. Census data, in this case, allow an inductive exploration of land use and land cover change that may provide clues to the underlying dynamics involved. These writers coined the terms 'socialising the pixel and pixelising the social' for making remote sensing, in general, more relevant to the social, political and economic problems and theories pertinent to land use and land cover change; in this case census data could also play a significant role. This objective involves methods and tools, 'predominantly GIS', which are relevant to the analysis of spatial imagery and 'gridded' data in general for exploring the underlying human model. Given the spatial data and GIS capabilities, hypotheses could be drawn to understand the spatial meaning of land use on the basis of a census-based spatial demographic model.

Several authors (Bracken and Martin, 1995; Dorling, 1995 and 1994; Findlay and Boregegard, 1995, Langford and Unwin, 1994; Lo, 1986; Martin, 1998; Openshaw, 1995; Rees, 1995; Wood and Skole, 1998), focused on the potential role of GIS technology and/or relevant issues in the field of Census Geography, though they did not mention remote sensing in this regard. Moreover, some authors (Antrop, 1998; Edmonds and Kyle, 1998; Enwistle *et al.*, 1998; Milanova, *et al.*, 1999; Fresco, 1996, Haarington, 1996, Skole, 1994; Spaling and Wood, 1998; Zaishi, 2000, Zinyama, 1999), focused only on land use / land cover changes over the time period, which can help to understand the socio-economic 'context' of the census data or dwelling unit or settlement patterns. However, Mesev

(1999), Lo, (1997) and Vector (1999) called for greater integration between census data and remote sensing in the much-neglected field of image classification and they further commented that GIS could make substantial in-roads in the quality of information.

To carry out this type of research, it is important to focus on some of the main quotations remarked by prominent authors. Their views may help partly to understand the dimension and scope of the research. The issues will be pointed out to comprehend the basis, presumption, necessity, temporal and spatial resolution of data, favourable circumstance, and thus, future direction of this research framework. These are, in brief:

(a) The role of GIS-remote sensing with population census data

"Greater integration between census data and remote sensing in the much neglected field of image classification and ...GIS can make substantial in-roads in the quality of information (Mesev, 1999)." In this study, the need of integration of GIS-RS is highlighted. Following this, I plan to develop a census-based classification technique, which may be described ultimately as a new census change detection technique with the help of remotely sensed images.

(b) Population estimation verses remote sensing

"Remote sensing techniques may provide population estimates that approach the accuracy of traditional census methods if sufficiently accurate in situ data are available to calibrate the remote sensing model. Unfortunately, ground-based population estimation may be inaccurate (Clayton and Estes, 1979)." Here, the accuracy and superiority of remotely sensed techniques over traditional census methods is criticised. Further, if we can use both techniques for the population counting and identifying their geographical locations, the resulting model must play a better and meaningful role for planning and resources management. For example, from the census report, we know the total number of population with associated parameters and, by the use of remote sensing, we will be able to pin point the concentration of geocoded population within an ED boundary.

(c) Quality of census data in the developing countries

"In many instances in developing countries, remote sensing methods may be superior to ground-based methods (Jensen and Cowen, 1999)." I have observed in the census data of the study area that some of the mauza population were missing despite the field evidence. With the help of remote sensing images, this type of error can be minimised or may be corrected reasonably.

(d) Cost of updating land-use change mapping

"Preparation of the land use maps by conventional methods is very time consuming and expensive. Moreover, ground surveys may be tedious in some areas. Also, the changing land-use patterns require a frequent updating of existing land-use maps of the area (Carlson and Sanchez-Azofeifa, 1999)." Due to the huge cost of updating, in Bangladesh, only the 1910, 1973 and 1994 land-maps were updated at the 1:50,000 scale. Cheaply available satellite remote sensing images, like CORONA, can play a significant supplementary role.

(e) Absence of long term census tract (EDs) data based on an identical boundary

"...temporal comparison of data from two successive censuses is by no means straight forward. First, censuses are not necessarily comparable in the forms of their questions and their content. Second, ... there are significant geographical and data structuring differences (Bracken and Martin, 1995)." In the UK or most of the countries in the world, the boundaries of an enumeration district (EDs) or a census tract is changed during the inter-censual periods. In the case of Bangladesh, and Savar upazila in particular, the definition or jurisdiction of lowest size of the census tract (mauza) has remained unchanged. We therefore have an opportunity to perform an analysis of historical land use change based on in-depth research and this will help to demonstrate the potential for planners and policy makers of integrated RS/GIS modelling.

(f) Resolution of Remotely sensed data to identify structures

"The imagery must be of sufficient spatial resolution to identify individual structures even through tree cover and whether they are residential, commercial or industrial buildings assumptions (Forester, 1985; Lindgren, 1985; Lo, 1986; Lo, 1995; Holz, 1988;

Haack *et al.,* 1997)." In my study, for the first time in this field of research, I will use very high resolution satellite images, like those from the modern IRS-1D commercial satellite and the recently declassified CORONA images, and integrate them with aerial photos and census data. The question of spatial resolution is less of an issue in this type of methodology.

(g) Availability of parallel spatial and temporal resolution of data-image

"The question is whether the parallel remote sensing and social data are available in forms of that are compatible (Rindfuss and Stern, 1998)." Parallel remote sensing data and census data of Savar upazila will be used for the period since 1951. They are highly compatible and relevant. The details are discussed in the next chapter with necessary tables and figures.

(h) Importance of field experience for interpretations

"Success in photo interpretation varies with the training and experience of the interpreter, the nature of the objects or phenomena being interpreted, and the quality of photographs being utilised. In addition, the interpreter has a thorough understanding of the phenomenon being studied as well as knowledge of the geographic region under study.... Photographs contain raw photographic data. These data when processed by a human interpreter's brain, become usable information (Lillesand and Kiefer, 1999)." A detailed field work plan has been formulated for this research and interviewing people was important to understand their knowledge and concern about land transformation over the time frame (1951-2001) of the research and beyond.

(i) Explaining satellite image from social aspects

"Remote sensing is expensive and government spending on it is more justifiable if it improves our understanding of the social systems by being incorporated into social science research. In addition, the contribution of social scientists might allow remote sensing experts to 'see' landscape features in the remotely sensed data not previously apparent (Rindfuss and Stern, 1998)." In a developing country like Bangladesh, this argument must be more practical and acceptable for various reasons, e.g. constraint of monetary and physical resources in comparison to the developed world.

However, it should be made clear at this stage that the primary goal of the research is not complex mathematical calculations or digital computation efforts to develop new models. The basic issue is to develop applicability guidelines for the integration of census data and remote sensing data for social applications rather than developing a new mathematical model or algorithms for testing. That means, the successful application using innovative approaches of the existing data-images for achieving goals is the main target of the study.

1.3.0. Brief Methods of Study

Before we discuss the brief methods of study, it is essential to recap the sources of major data which will be linked with the methods. Furthermore, for every analysis chapter, I will give further details of the methods applied in that chapter as and where necessary.

The major sources of high resolution remotely sensed data are: Aerial Photos b/w and IR (1953, 1984 and 1990); CORONA KH4 & KH4b spy satellite panoramic microfiches (1962 and 1972); IRS-1D 0.50-0.75 microns spectral band (2000); and DGPS based GCP coordinates of 2001. Digitally converted conventional and historical administrative, land use, planning, revenue and topographic maps are also used at a large-scale resolution up to the 1:3,960 scale. Moreover, the 1951, 1961, 1974, 1981, 1991 and 2001 population censuses are used in parallel to help interpret images and surrounding factors. An in-depth survey was conducted as well during the fieldwork in four selected mauzas to help interpret and develop a land cover and population change.

The Table shows the resolution of the remotely sensed images with its other parameters. In fact, where settlement identification is important, this type of survey requires high spatial resolution remotely sensed data from ≤0.25 to 5 metres (Forester, 1985; Lindgren, 1985; Lo, 1986; Lo, 1995; Holz, Phillip *et al.* 2002; 1988; Haack *et al.* 1997). The high spatial resolution panchromatic sensors may provide a good source of information for monitoring the housing stock of a community on a routine basis. This will enable local governments to anticipate and plan for schools and other services with data that have a much more frequent temporal resolution than the decennial census (Jensen and Cowen, 1999). These data will also be of value for real estate, marketing, and other business applications (Lo, 1995). Research is required to document the utility of the method in a variety of cultures and population densities. Land use in an urban area is closely correlated with population density. Researchers can establish a population density for each land use by field survey of census data. Then, by measuring the total area for each land-use category, they can estimate the total population for that category. Summing the estimated totals for each land-use category provides the total population projection (Lo, 1995). Later it is argued by Rindfuss and Stern (1998) whether the parallel social data are available in forms that are compatible.

For any further analysis of GIS and Remote Sensing with the census data, there must be a link between GIS and Remote Sensing. A brief discussion on the integration of GIS and remote sensing, therefore, is essential. In the following section I will focus on some of the literature associated with the integration of GIS and Remote Sensing, a brief data capturing method, various land use and land cover change analysis techniques and the meaning of change detection, and so on. A basic link between census data and remote sensing will also be established. Finally, based on literature survey and understanding, I discuss the plan of the fieldwork strategy and current gaps in the published literature in the context of my study.

1.3.1. Why the Integration of GIS and RS?

A brief working definition of a Geographical Information System (GIS) may be a 'computer based system for the efficient input, storage, manipulation, analysis, representation and retrieval of all forms of spatially indexed and related descriptive data'. An emerging trend in GIS applications is the use of multiple systems and diverse data sets in a single study. Recently, much emphasis has been placed on the integration of remotely sensed imagery from image analysis systems (IAS) with other digital spatial data from GIS. It is widely recognised that this type of synergism has the potential to open new avenues for both (Estes, 1985; Jackson and Mason, 1986; Goodenough, 1988; Piwowar and LeDrew, 1990). In fact, many scientists are already using a number of different IAS and GIS in a single project to take advantage of the processing capabilities that some systems have and others do not (Abel, 1989). In practice, sharing spatial data among different systems is difficult because of the unique way in which each system stores and processes its data.

GIS is a means of assembling and analysing diverse data pertaining to specific geographic areas, using the spatial locations of the data as the basis for the information system. In the broadest context, GIS identify a user's data needs, and channel the data to the intelligence level at which decision-making takes place. Estes (1992) indicates that GIS can:

- Facilitate access to information;
- Facilitate the creation, updating and modification of maps;
- Improve our ability to model important science research questions and operational resource management tasks;
- Enhance graphic display of complex phenomena; and
- Provide tools for enhancing decision-making.

Remote Sensing provides a source of data for such systems and has the potential to improve the quality and quantity of data available. In some ways, remote sensing can contribute data which never existed before in such systems (Donoghue, 2001 and Estes, 1981). The true effectiveness of RS inputs to information systems, then, can be measured by the appropriateness, timeliness and accuracy of data provided to the system. These in turn are functions of the effectiveness of GIS as a whole. The data accumulated based on RS systems can be put to their best use if they are incorporated in a system capable of efficient data storage and expedient data processing and retrieval.

Therefore, the basic differences between GIS and RS systems are narrowing rapidly. GIS is a demonstrably powerful tool for the management and analysis of spatial data. RS systems are demonstrably powerful tools for the collection and classification of spatial data. In the last few years, there has been an increase in interest in the direct use of RS data as an input to GIS. But much of this interest has been centred in the potential primary uses for those who make operational use of GIS. Many researchers feel that the use of GIS and RS together can lead to important advances in research and operational applications. Merging these two technologies can result in a tremendous increase of their potential for a wide range of applications.

Increasing attention is given to the practicability of Remote Sensing (RS) and Geographical Information Systems (GIS). Easily adaptable low-cost systems in these two rapidly advancing technologies have particular relevance for both developed and developing nations. The GIS have extended the capability of low-cost digital systems that simply provided storage and map production capabilities, to systems providing spatial data analysis including the linkage of spatial data and spatially related attributes. Data capture is an essential but laborious and expensive component of the overall mapping system.

Satellite RS is an obvious source of data for mapping and map revision because of its repetitive wide-area coverage and low cost. The integration of RS and GIS is thus both possible and desirable and is rapidly emerging because of the complementary role played by these technologies in resource management. The current trend toward more emphasis on the application of Integrated GIS stems in part from (Estes, 1992):

- Improvements in the quality and quantity of data;
- Improvements in computer hardware and software;
- Increasing population and competition for natural resources;
- Decreasing resource availability and environmental quality;
- Recognition of the global nature of problems; and
- An increase in the number of public and private organisations working on local, national, regional and international problems, and the creation of larger and larger databases to provide information on these matters at various scales.

The problem is to identify the appropriate field in this context. So far, the largest source of information for GIS is census data, while the biggest source of remote sensing images is satellite platforms. The relationship between the satellite database and the census database is one of the prime interests of this study. The following section is basically focused on the importance of the relevant issues.

1.3.2. Data Capturing Methods in GIS

Now we will consider some basic principles of GIS, which are relevant for this study. The first and most obvious point is the ability of GIS to handle large amounts of data. In the study area mapping and assessment have only just begun fully to utilise computer-based spatial analysis in order to regulate data, image, shape, grid and test models. The data quality for development planning assessment involves the identification of the study areas using of GIS/RS techniques for various problems of monitoring, quantification and to help with the establishment of appropriate appraisal systems for monitoring, evaluation, and forecasting of impending events. The purpose of an attribute data evaluation model is to predict and to provide new information about the situation being analysed. This model involves four steps: *problems of formulation, data manipulation, interpretation and analysis* and *the display of results* (Rashid, 1996). The purpose of this model is to develop upazila level planning, proper policy making, quick programme formulation and so on within a short period of time.

The data held within a GIS differs from that held in order systems because it also holds information on the spatial location and attributes of each object or point documented. Geographical data can be reduced to three basic types: points, lines and polygons. An infrastructural feature would therefore be represented by an X or Y co-ordinate and 'find number', whilst a road would be recorded as a string of co-ordinate pairs and its name. An urban area would be defined as a string of co-ordinates forming a polygon surrounding the area along with a descriptive label. Each planning parameter/component based map is defined by the sum of such features and is composed of a group of points, lines and areas identified by their spatial position and their non-spatial attributes.

1.3.3. Sensors for Land Use Change Studies

There is almost no known in-depth research work on land transformation using four basic components at the same time like RS, Census, Plot Level Maps and Field Data. But there are several arguments of land use change mapping and the change detection methods. These are discussed below briefly.

(a) Conventional and Sensoral Land Use Mapping

Remote sensing provides multi-spectral and multi-temporal synoptic coverages for any area of interest. Satellite data provide a permanent and authentic record of the land-use patterns of a particular area at any given time which can be re-used for verification and re-assessment. The digital format of satellite data gives it a tremendous flexibility. On the other hand, GIS provides the facility to integrate multi-disciplinary data for dedicated interpretations in a easy and logical way. This integrated approach proves to be time-saving and cost-effective. Studying changes in land use patterns using remotely sensed data is based on the comparison of the time sequential images. Differences in surface phenomena over time can be determined and evaluated visually, using digital techniques (Grag *et al.,* 1998, SAC, 1990). Change detection using satellite data can be efficient for timely and consistent estimates of changes in land use trends over large areas, and has the additional advantage of ease of data capture into a GIS. In Table 1-2, I have listed some ideas on how the information system may help through its attribute facilities.

(b) Multi-Sensoral Change Detection Studies

Change detection is a major application of the analysis of remotely sensed data and is suitable for land transformation study. Change detection involves the use of multi-date data sets to discriminate areas of land cover change between the dates of imaging (Sunar, 1998). A number of techniques for accomplishing change detection have been formulated, applied, and evaluated and several reviews of change detection techniques have been conducted. Change detection is the process of identifying differences in the state of an object, a surface, or a process by observing it at different times (Singh, 1989). The underlying assumption in using remotely sensed data for change detection is that changes in the land-cover result in significant differences in the remote sensing measurements between two or more dates. In addition these differences must be larger or somehow distinguishable from other changes in the images due to changing atmospheric conditions, seasons, illumination condition and sensor calibration (Abuelgasim, *et al.,* 1999). Among many factors governing selection of a change detection strategy are information requirements, spectral coverage, data availability and quality, image processing resources, analyst skill and experience, phenomenological knowledge, time and cost constraints and the importance of labelling the changes that are detected.

Table 1-2: Example of Feature Types or Layers for the Study

Major Features	*Feature Class*	*Input Attributes in Arc/Info*	*Main Purposes to select the layers*
Roads	Lines	Type of roads	To understand the road facilities of any development parameters and to see the history of them according to types (*e.g.* highways, rural roads)
Rivers	Lines	Types i.e. khals, distributaries, rivers etc.	To locate the water bodies of the study area and indicate potential risk areas (i.e. flood and river bank erosions)
Beels	Polygons	id numbers	To indicate that these areas are suitable for fisheries resources
Mauzas	Polygons	Geocode based all census data	To add all attribute/census data and calculated data including daag (plot) numbers
Union boundaries	Polygons	Union names and statistical data and attributes	To show the intra-unions disparities of different facilities and associated items.
Paurashava	Polygons	Urban area	To draw the major planning intentions of the upazila
Settlements	Polygons	Census data	To calculate and visualise the population density in a enhanced form
Land type	Polygons	Inundation data	To classify the soil series in land type information according to their inundation level
Schools	Points	GPS coordinates of Government Primary Schools	To draw the buffer of each school and evaluate there location according to settlement pattern

Source: Author, 2003

More than 75 Change Detection techniques have been tested so far (Yuan *et al.,* 1998). Out of these, only Multi-Sensoral Change Detection Studies (Igbokwe, 1999) are notable in the current context. These usually involve precise geometrical processing of the image data before interpretation. In others, more complex geometrical rectification (geocoding), two dimensional image correlation and image rectification are involved. The techniques can easily be integrated into change detection schemes, for example, in land cover/land use analysis, for map revision and physical planning. The resolution of image data matters a lot in this technique. The use of images with suitable resolution will help to increase the overall registration accuracy. Since the method discussed involves the use of multi-sensoral images, the resolution of different image data should be the same and where they are different, the required resolution can be reached through intensity interpolation. Pre-processing may be necessary to enhance the visual quality of the image set. Texture analysis can be applied where necessary. Appropriate filtering techniques could also be used to enhance the quality of the image. The nature of pre-processing depends on the quality of the available images. The resultant accuracy of 0.28 pixel is very good and satisfies map revision needs. A small study area will reduce the volume of computation work.

1.3.4. Method of Integrating Census Data with RS

Jensen and Cowen (1999) highlighted the use of remote sensing images for population estimation and census data assessment. According to this guideline, selected socio-economic characteristics may be extracted directly from remote sensor data or by using surrogate information derived from the imagery. Knowing how many people live within a specific geographic area or administrative unit (*e.g.* city, county, state, country) is very powerful information. In fact, it has been suggested that the global effects of increased population density on eco-system land-cover conversion and human well-being may be much more significant than those effects arising from climatic change (Skole, 1994), e.g. the relation between settlement pattern and flooding condition in the study upazila. Population estimation can be performed at the local, regional and national level based on:

counts of individual dwelling units, measurement of urbanised land areas (often referred to as settlement size), and estimates derived from land-use/land-cover classification (Lo, 1995; Sutton at al., 1997).

Mesev (1998) has shown the use of Census data in Urban Image Classification. Though he did his work based on one year only, he has formulated a very important way of thinking which is of relevance to this research. In this paper, he outlined and demonstrated a supervised classification strategy containing a suite of techniques that allowed the linking of urban land cover from remotely sensed data with urban functional characteristics from population census data. For a stronger link, census tract data were also interpolated into a more desegregated and more precise raster-based surface, then used to modify maximum-likelihood classifications through stratified class a priori probabilities, and in terms of assisting the selection of training samples and contextual post-classification sorting. The strategy was applied to the classification of housing density of four settlements in the UK.

Census data and interpolated surfaces of census data are incorporated into standard supervised image processing at three stages: before, during and after classification (Hutchinson, 1982): i.e.

- Before, or pre-classification, census surfaces are used to assist the selection of class training samples;
- After classification, census surfaces are used to assist in post-classification sorting; and
- During classification, census data in tabular form are normalised and used as class a priori probabilities in a Bayesian modified maximum-likelihood estimator.

Before examining this tree-forked strategy, Mesev (1998) emphasised the need to define and conceptually justify the use of tabular and surface based census data. He added that socio-economic and housing data from national population censuses are represented as aggregated spatial units, known as census tracts (in the UK these are enumeration districts, EDs, while in Bangladesh they are known as Mauza). If research is at the city level, a collection of interrelated census tracts can be accurately and reliably used to calculate a number of functional attributes (for instance, population size, social composition, housing type, etc.). As census attributes are assumed to be uniform within a census tract, there is no relation between a settlement's physical structure and its functional characteristics. In other words, within a census tract land cover and land use are unrelated and indistinguishable. What is needed is a means of disaggregating the census tract and filtering out areas that are non-built up and non-residential. Remotely sensed data are a convenient source for separating built form from open spaces and vegetation, and, to some degree, separating buildings that may or may not be used for residence. Where image data fall short, support can be given from census data which are spatially manipulated to determine more accurately the location of residential land use. The basis for this manipulation is the use of population-weighted centroids which act as pointers to where within the tract the greatest concentration of residential land use is located. By using distances between centroids, a surface can be interpolated taking into account residential density and, therefore, an approximation of the residential, not urban, geography of settlement.

The above discussions are useful in the context of the current research but there are no specific papers on a possible elaborated field work strategy. Additionally, I have reviewed most of the census and remotely sensed data have been analysed by different authors for a single year of study, but there are no examples which can help to develop historical population change studies based on decennial census reports. I found that the lack of high resolution parallel remotely sensed data and the problem of constant EDs over the past decades were the main difficulties. For example, the EDs for the 1951 and 2001 census were not the same, so it is not possible to study long term population datasets. In my study I had a unique opportunity to overcome this problem.

1.3.5. Fieldwork Strategy

There was a plan to visit the study area early in second year of my research for four months. The field work strategy is basically for the following purposes:

(1) **Intensive DGPS (Differential Global Positioning Systems) Survey**: GPS Survey played an important role in updating conventional maps and in identifying a sufficient number of GCPs (Ground Control Points) for georeferencing and geometrical correction of remotely sensed images. A general GPS survey of all metalled *(pucca)* and unmetalled *(kacha)* roads of Savar upazila was georeferenced. GCP for major infrastructures and ancient large ponds *(pukur)* are also important. Moreover, I used very GCP precisely for selected villages in detail as conventional map data are not properly geo-referenced.

(2) **Ground Verification:** Preliminary classified satellite images and aerial photos were verified during the field work. Some unknown features are visible on the remote sensing images, and the field work helped to explain these properly.

(3) ***In Situ* Investigation:** A detailed questionnaire survey, interviewing and observation techniques was conducted during the field visit. It was important to understand the causes of land change, population patterns, impact on the extent of agriculture land and the overall interpretation of data. Planning policies adopted by the local, regional and national authorities were documented. A participatory mapping method was used to understand the change of the area over 50 years using the local people's knowledge-base.

(4) **Observing and collecting census data 2001:** The census survey of 2001 of Bangladesh was conducted in January. Raw census data was collected and processed during the fieldwork.

(5) **Aerial Photos:** It is not possible to bring hard-copy Aerial-Photos out of Bangladesh. Therefore, primary interpretation, elementary processing and vital digitising work of the available APs were done during the field work and scanned and processed copies of them stored in digital format in order to do further in-depth analysis in Durham.

(6) **Data Collection:** Relevant maps, information and data published by the local authorities in Bangladesh and not available in the UK, were collected and photocopied. For example, I planned to conduct a detailed plot to plot survey on six villages during the work. The village (mauza) maps were available in the DLRS (Directorate of Land Records and Surveying) of Bangladesh. These maps were purchased at that time. The scale of field data would be 1:3,960. The data and information were collected using questionnaire and interviewing of the selected focus group (e.g. elderly prominent local people, *matabbar*, members of the union *parishad*), observation and other related methods. A standard land use map was prepared of the sampled areas with the help of local people.

(7) **Participatory Remote Sensing:** A new concept on "participatory remote sensing" was introduced using CORONA satellite photographs using local knowledge on an experimental basis. The CORONA Military satellite imageries of 1962 and 1972 are available in the form of negative film. The film is very easy to print out through traditional photographic film processing labs. These printed products were easily understandable by the local selected focus group. In the first phase, they mapped their own village without having the photos and later, they did the same job with the help of CORONA data. They also explained the reasons behind the change. Also, they interpreted the image better than the readily available image processing techniques.

(8) **Surveying Sampled Village:** The status of mauzas (broadly villages) is not same as in the 1950s. Some villages are changing very rapidly and some are not, due to the

surrounding environment and development contexts. Therefore, some criteria of selecting villages were followed. But in most cases, I have related Bara Oalia as a detailed example in the research because the word limit of this thesis prevents discussion of all of the selected (four) mauzas.

(9) **Census Data Problem:** Some of the mauza census data (e.g. in 1974) are seemingly not available in the BBS Census Reports. These were verified and checked during the field work.

The overall field work activities, played a very important role in this research to assist and interpret census and remote sensing data and images.

1.4.0. Various Research Gaps

There are no specific papers that I have found on a possible field work strategy for remote sensing experts for collecting social data and also there is no literature on how we can use historical parallel data and image simultaneously for the study of land transformation and what would be the role of large scale maps in this regard. It is assumed that the following gaps of research should be filled in order to reach to the goal of this research.

The current study has focused on how to minimise the gaps when the integrated approaches of various sources of information are required. From the discussion so far in the research, if we can think about the gaps in order to support each other, the following four broad areas can be identified. The goal is to make them compatible for the land transformation study. These are vital interrelated and interdependent gaps for integration amongst: (1) remote sensing, (2) population censuses, (3) field data and (4) conventional maps.

(1) Gaps in the use of the remote sensing for change detection along with other fields of research like population census, map integration and field data incorporation.

(2) Gaps of the census data for population trend analysis with the help of remote sensing, fieldwork and remotely sensed data.
(3) Lack of in-depth field study to interpret and integrate vast sources of information like remote sensing and population censuses.
(4) Also how to integrate historical valuable maps, which have been neglected so far by policy makers but should have been taken more seriously. For example, mauza maps of Bangladesh could play a significant role in land system change analysis.

However, we should see the elements of gaps collectively instead of individually as shown in Figure 1-3.

1.5.0. Organisation of the Thesis

Chapter 1 focuses on the primary issues of the study including the aim and objectives of the research. I have highlighted the relevant literature review for the study of land transformation under various context and themes. Also, a primary background of the study upazila is briefly outlined as well as various aspect of the methodology, basis sources of data and gaps in the research.

The cornerstone of the thesis is **Chapter 2.** Without organising and preparation of the databases I could not have performed any further analysis. All essential aspects of the available sources of data and their digital conversion for the analysis are discussed here. The chapter starts with a description and context of the study area.

All decennial remotely sensed high resolution imagery are interpreted in **Chapter 3** using some recognised and some new elements of interpretation method and ground truthing. This section has the basic sources of all land features mentioning local terms linked with the land transformation and their context and history over the last five decades.

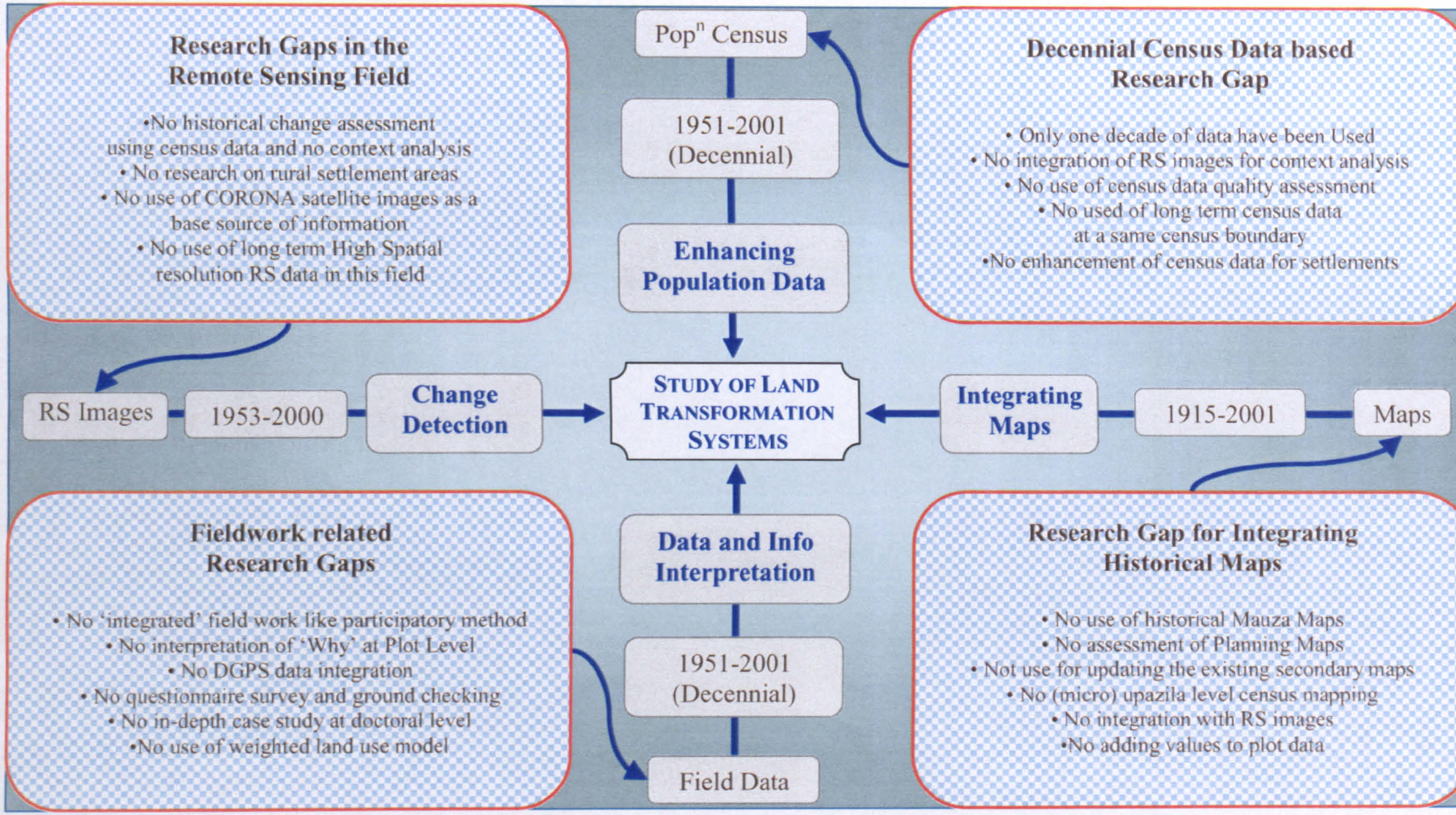


Figure 1-3: This research is based on map data, census data, aerial photo images, satellite images, GPS data and data collected from the field. The diagram show how the overall data will be integrated for this study in the light of research gaps and existing database. Here, very raw methodological designs have been developed in terms of gaps for the integrated study approach of land transformation.

The main consideration of **Chapter 4** is to integrate census data with the remote sensing images. Here the most significant task is to enhance the resolution of census data from mauza to sub-mauza scale.

Chapter 5 gives a taste of quantification and ranking of transformed land. The union (sub-upazila) level analysis gives a comparatively clear picture of the rate of transformation and the possible reasons behind it. New sets of approaches for population density calculations are introduced here to monitor land at decennial intervals of time.

From the broad upazila based study, now I will enter into a micro scale study at mauza level in **Chapter 6**, where the importance of remotely images sensed is highlighted and illustrated with the help of plot-based historical land tenure systems and with the help of local villagers. The centre of gravity of development is identified using unexplored visual, geo-statistical and image processing methods explaining the output of the findings.

Chapter 7 is the final section of the research where the concluding remarks have been placed and the overall scenarios of the thesis are discussed briefly, with some recommendations and issues involved with land transformation, planning and policies.

1.6.0. Conclusion

The proposed research work, it is hoped, will serve as an exemplar to guide the policy makers, historians, image analysts, geographers and, above all, will offer a handshake between social scientists and RS scientists. For academia, it will assist in understanding the links between census and satellite data and so help to link people with pixels. An output of the research, hopefully, will also assist in 'socialising the pixel' and 'pixelising the social' by mining pixels using census data and interpretations from pixels using RS images for understanding rapidly changing land cover in a meaningful way.

From the overall discussion, we can have the following pre-assumptions as requirements. These are:

(1) High spatial resolution satellite images;
(2) Decennial census data with same enumeration boundaries;
(3) Parallel long term census and remote sensing data;
(4) DGPS data up to plot level at sub-metre resolution;
(5) Conventional maps in digital form;
(6) Dynamic land cover changing due to rapid population growth; and
(7) Georeferenced Field-data, Field-experience and Field–evidence.

If I summarise some of the central issues of this research, I can list the following areas:

(1) Contextualising the complexity of land use, land cover and physiographic change in developing countries;
(2) Demonstrating a robust methodology for high spatial resolution remotely sensed imagery for interpreting land use change;
(3) Showing a new dimension of historical census and field data, capable of integration with parallel remotely sensed data as both enhanced and pixelised forms;
(4) Evaluation of new sources of high resolution RS images, e.g. CORONA, IRS-1D (also applicable for IKONOS, QuickBird and so on, but these are not used in this research). These data are unbiased and available for large areas and the nature of impartiality is the most important issue for any underdeveloped nation and will also to help investigate the weakness of the currently available secondary data/maps; and
(5) Mauza maps are large scale land ownership maps but are not used for other purposes. By adding topography, land-use, land value, census and other plot level data, these maps (available from 1910 onwards) will have value for research and planning across the Indian sub-continent.

Savar upazila will be a test case for academics on the one hand and policy makers on the other. The study will try to establish the complementarities between RS and Population Data, where social-physical phenomena will join together with the enriched field experience. Both areas were developed independently to some extent, especially in the early days. By linking the technologies, the concept and theories of both integrated geographical information systems can be considerably richer and more sophisticated for use in substantive applications for planning and development of an upazila's overall environment and social benefits.

Chapter 2

CHAPTER 2: STUDY AREA WITH SOURCES OF DATA AND IMAGES

2.1.0. Introduction

The main focus of this chapter is to provide an in-depth understanding of Savar upazila. Only those sections of the study area have been documented here that are not discussed in the later chapters and which are highly relevant as the basis for an insight into the area. Also, the sources of primary and secondary data including remotely sensed images are discussed here. The entire structure and content of the thesis are highly dependent on the foundation laid in the following sections.

2.2.0. Study Area and its Context

Savar upazila headquarters is about 30 kilometres by road from the heart of the Capital and is connected by the Dhaka Aricha National Highway, one of the busiest roads of Bangladesh. The upazila occupies an area of 278 km^2, including 32 km^2 of river and 15 km^2 of forested area. According to the 1991 census report, the population of Savar upazila was the 378,034. It has a rapidly growing population and has experienced a change in its traditional agrarian land use during the last few decades due to the influences of urbanisation from Dhaka Metropolitan Megacity. For instance, during the pre-urbanisation census period (1951-1961), the decadal population growth rate of Savar was 24.6 percent, which was slightly below the national average. At that time the national population growth rate was 25.04 percent. After starting its urbanisation process, particularly during the 1981-91 census period, the population growth rate was almost double the then national average. The decennial growth of Savar was 44.30 percent while the national rate was only 23.96 percent. During the period 1991-2001, the rate of population increase was about 58 percent in the upazila, while the national growth rate was only 14 percent. In fact, Savar came into the limelight during the late 1980s when it became likely that it would be engulfed by the expansion of Dhaka. Since 1995, the study area has come within the jurisdiction of the RAJUK (RAJdhani Unnayan Kartipakhkhya, or Capital Improvement Authority, the plan for which has briefly been discussed at the end of this section) and so its overall development planning and implementation are supposed to be guided by this agency and at least theoretically this gave a special improved pro-urban status to the upazila.

(a) Geographic Setting

Savar is geographically located between 23°44'15.61" and 24°01'37.17" North and between 90°11'08.45" and 90°21'36.70" East. The respective Lambert Conformal Conic (LCC) grid references in metres are 664,108.209N, 696,095.056N, 2,762,060.639E, 2,779,888.394E. The upazila is bounded on the north by Kaliakair and Gazipur Sadar upazilas, on the south by Keraniganj upazila, on the west by Dhamrai and Singair upazilas and on the east by Mirpur and Mohammad thanas of the Dhaka City Corporation. Savar upazila is almost a rectangular shape and it is about 12 kilometres wide and 30 kilometres long with an area of 284.63 km^2. Savar upazila consists of 11 unions and one *paurashava* (municipality). In terms of its physical extent, it is an important part of the capital of Bangladesh. Its total area is almost double the size of all 90 wards (135.22 km^2) of Dhaka City Corporation. Moreover, its area is approximately equal to that of Dhaka Metropolitan City (304.96 km^2). Additionally, according to the jurisdiction/control area (1448.23 km^2) of the master plan (1995-2015), RAJUK's total area is 5 times bigger than the size of study upazila (see Figure 2-1 for the map on 'Savar as a Pro-Urban' area).

(b) Is Savar an Urban or a Rural Area?

There is a debate as to whether Savar upazila should be considered as a rural or urban domain. Because it is part of the Rajuk, and a municipality, various big government infrastructures are located here with urban facilities. Moreover, the Agriculture Census of 1996 (BBS, 2000) recorded it as urban domain. But the area is not completely rural and not a completely urban area. I prefer to define the upazila is a ***pro-urban*** area which has been transforming very quickly in the last decades. It is now a buffer zone of the rural-urban interface between the north-west and south-east of Savar.

According to the government, even Savar municipal cannot be defined as an urban area. The following is the definition of an Urban Area as set out by the Bangladesh Government and mentioned in the Bangladesh Bureau of Statistics, 1991:

Definition: Developed areas around:

(i) an identifiable central place;
(ii) where amenities like metalled roads, communication facilities, electricity, gas, water supply, sewerage, sanitation etc usually exist;
(iii) which is densely populated and a majority of the population are non-agricultural; and
(iv) where community sense is well developed.

Three different types of urban areas have been defined for the census by map:

(i) **Statistical Metropolitan Area (SMA)**: These are defined to include Municipal corporations and adjacent areas having urban characteristics.
(ii) **Municipality Area (M)**: Municipalities are incorporated and administrated by the government as urban areas under the Paurashava Ordinance, 1977; and
(iii) **Other Urban Area (U)**: These are upazila headquarters and development centres which have urban characteristics.

As mentioned in the BBS report, following international practices (Table 2-1), urban areas have been classified by size of population as Town (T), City (C), Statistical Metropolitan Area (SMA) and Megacity (MC).

Table 2-1: Classification of Urban area based on population size in Bangladesh

Town (T)	Population	City (C)	Population	SMA	Population
T1	Below 25,000	C1	**100,000-199,999***	M1	**500,000- 999,999****
T2	25,000-49,999	C2	200,000-299,999	M2	1000,000-1,999,999
T3	50,000-74,999	C3	300,000-399,999	M3	2,000,000-2,999,999
T4	75,000-99,999	C4	400,000-499,999	M4	3,000,000-4,999,999

Source: BBS, 1994

Megacities are urban areas with a population of 5 million or more and also fulfil the criteria of urban area. Based on the above description the Paurashava (municipal) area of Savar upazila belongs to the C1 category with a 132,435 (*) population in 2001. If we consider the entire upazila is a part of urban area then it would be in the M1 (**) category with a population of 635,508 at that time. However, if we use the parameters of urban services individually for each union, then we will find a more complex overall picture (Table 2-2).

(c) Rennell's Map of Dhaka in 1780

Most of the chala land of the study area was part of a dense shaal forest which is proved from the historical and earliest available map of 1780 of Dhaka. Figure 2-2 is the oldest available map of the Dhaka Region including the Savar *upazila* during the late 18th century, published by Major J. Rennell immediately after the establishment of the British Colony in the Indian Sub-continent. At that time, Dhaka (then known as Dacca) was a very small centre containing only a few thousand people and located in the "A" position on the red polygon on the northern bank of Buriganga River. The southern and eastern parts of Dhaka were physically obstructed by the rivers and lowlands, and are still highly vulnerable to the floods that occur each year. The northern two big green areas marked by

Table 2-2: Status of Savar upazila in the context of urban definition

Unions of Savar Upazila	Identifiable central place /growth centre	Densely Populated* (international rating)	Mostly nonagricultural Occupations	Amenities for majority (Serving more than 50 percent households)							Developed Community sense
				Pucca Road	Telecom	Electricity	Gas	Piped Water	Sewerage	Sanitation	
Amin bazaar union	X	T2	X			X	X				X
Ashulia union	X	T2									
Banagram union		T2									
Bhakurta union		T2									
Biralia union		T1									
Dhamsona union*	X	T4	X			X					
Kaundia union		T1				X					
Pathalia union*	X	T3									
Savar Paurashava	X	C1	X	(X)	(X)	X	X				X
Savar Union*		T1	X			X	X				
Simulia Union	X	T3									
Tetuljhora union		T2				X					
Yearpur union		T2									
Government Institutions**	X	T1	X	X	X	X	X	X	X	X	X

Sources: BBS, 1994 and Fieldwork (i.e., **X***), 2001*

Notes*: Government or Autonomous institutions have not been included in these unions' jurisdiction, as they do not have general public access and are run by self-governing-authorities, which are completely separate from the union and paurashava parishads (councils), for example**: Jahangirnagar University, Savar Senanibas, PATC, EPZ, Government Dairy Farms. Density is calculated from the 2001 population census statistics. **(X)** indicates serving less than 50 percent inhabitants.

See for definition <u>pages 4-5</u> of Bangladesh Population Census 1991 (Community Series for Dhaka Zila), Dhaka: Bangladesh Bureau of Statistics (BBS) 1994.

"B" and "C" were deep Shaal (*Shorea Robusta*) forests in this region at that time. The areas are relatively high land and mostly flood free. As it was not a part of flood plain, the area was also not suitable for agricultural crops. Over the last two hundred years, firstly the "A" region and then the "B" marked forest have mostly disappeared due to demands for the valuable timber in Bengal and in the UK. After getting independence from the Great Britain in 1947, Dhaka got the status of capital of the then East Pakistan (1947-1971) and later Bangladesh, and attracted a massive population growth and development activities. Dhaka city started to expand towards the north and the north-west former forested areas. Currently, the modern and densely populated Dhaka Metropolitan City

(DMC) is situated in the "B" marked green region, with a population of about 7 million. The city is now heading to the "C" region, known as Savar upazila, in order to expand its territory to that of RAJUK. Savar is almost equal in size to the DMC. The map also shows the relative location of the study mauzas, i.e. 1=Ganda, 2=Bara Oalia, 3=Banshbari and 4=Bara Kakur.

(d) A Brief Physiography

The study area covers the Lower Madhupur Tract and the Lower Brahmaputra Floodplain, which has an undulating topography of both Pleistocene and recent formations, where geomorphological processes are distinctly different and pedological evolution is in different phases of development. Altogether three broad types of landforms can be identified on the basis of drainage, elevation and pedological characteristics. These are locally known as '*Chala /Taan /Tek/ Tenguira*' (highland, medium highland), '*Byde*' (medium high to medium low land), and '*Naama/Chwak/Chars*' (low land and very low land/depressions). The *chala* lands are normally flood free, relatively less productive for rice but extensively used for vegetable cultivation throughout the year and famous for tree plantations, particularly Jack fruit plantations and Shaal Forests. Also, the Chala land is the first choice for permanent infrastructural developments. However, the chala lands are dissected by the *Bydes*, which usually remain shallow to deeply flooded for the three to four months between July and November. The Bydes are fertile, rich in clayey soil and mainly used for a single crop, predominantly HYV boro rice. The Naama covers the major agricultural lands where prolonged flood waters from Dhaleshwari, Bansi and Turag rivers affect the area quite regularly. The seasonal flooding during the monsoon remains for four to five months between June and December. The depressed area is flooded for more than five months and HYV boro rice is cultivated here. The back slopes of the floodplain are used for rabi and deep water rice. In general, in the study area, there is 38 percent high land (flood-free), 21 percent medium high land (occasionally flooded), 10 percent medium low land (regularly flooded), 16 percent low land (facing prolonged flooding) and 15 percent very low land (perennial bodies).

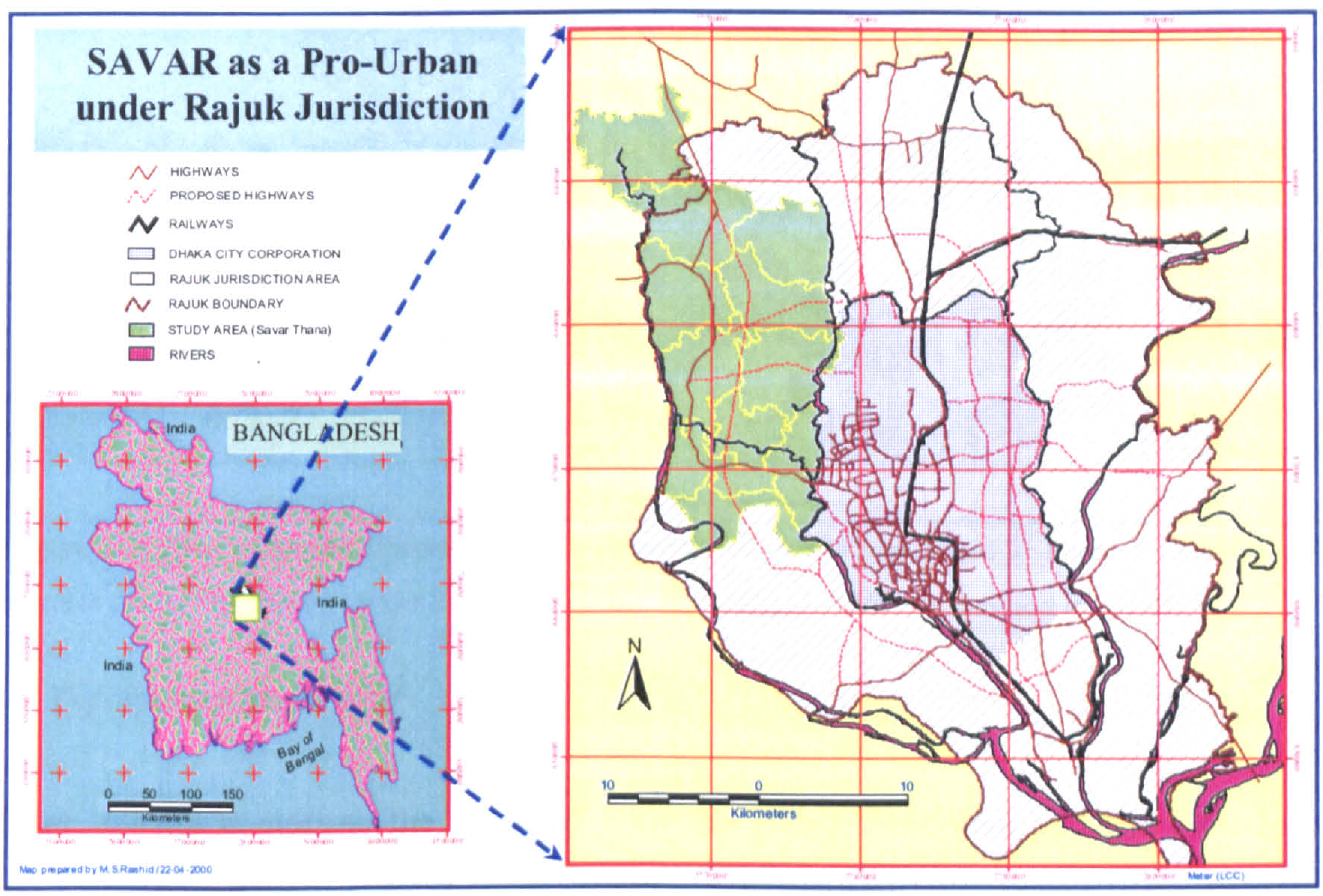


Figure 2-1: Savar upazila (the Green Zone) is the 17th Strategic Planning Zone (SPZ) of RAJUK situated in the north-western part of the capital city demarcated as the City Corporation of Dhaka (inner dark grey part). Savar can be termed a pro-urban (and in some cases pro-development) area rather than a suburb or peri-urban. By Rajuk definition, it is a part of the capital Dhaka but there are few or no urban utility services. For example, only 1-2 percent of the population of Savar gets a service of flowing water or street light at night, in restricted belts controlled by government bodies. In general the ordinary public has no access to basic urban needs. Dhaka is also partly dependent on Savar due to the location of big infrastructures like industries, e.g. EPZ, and educational establishments, e.g. University. At the same time Savar is also partly dependent on the Capital City. Dhaka was originally located in the south-east and expanding to the north-west. It is projected that Savar will be a full part of the Capital by 2015 if the government implements its promises as underlined in the master plan in 1995 for this area.

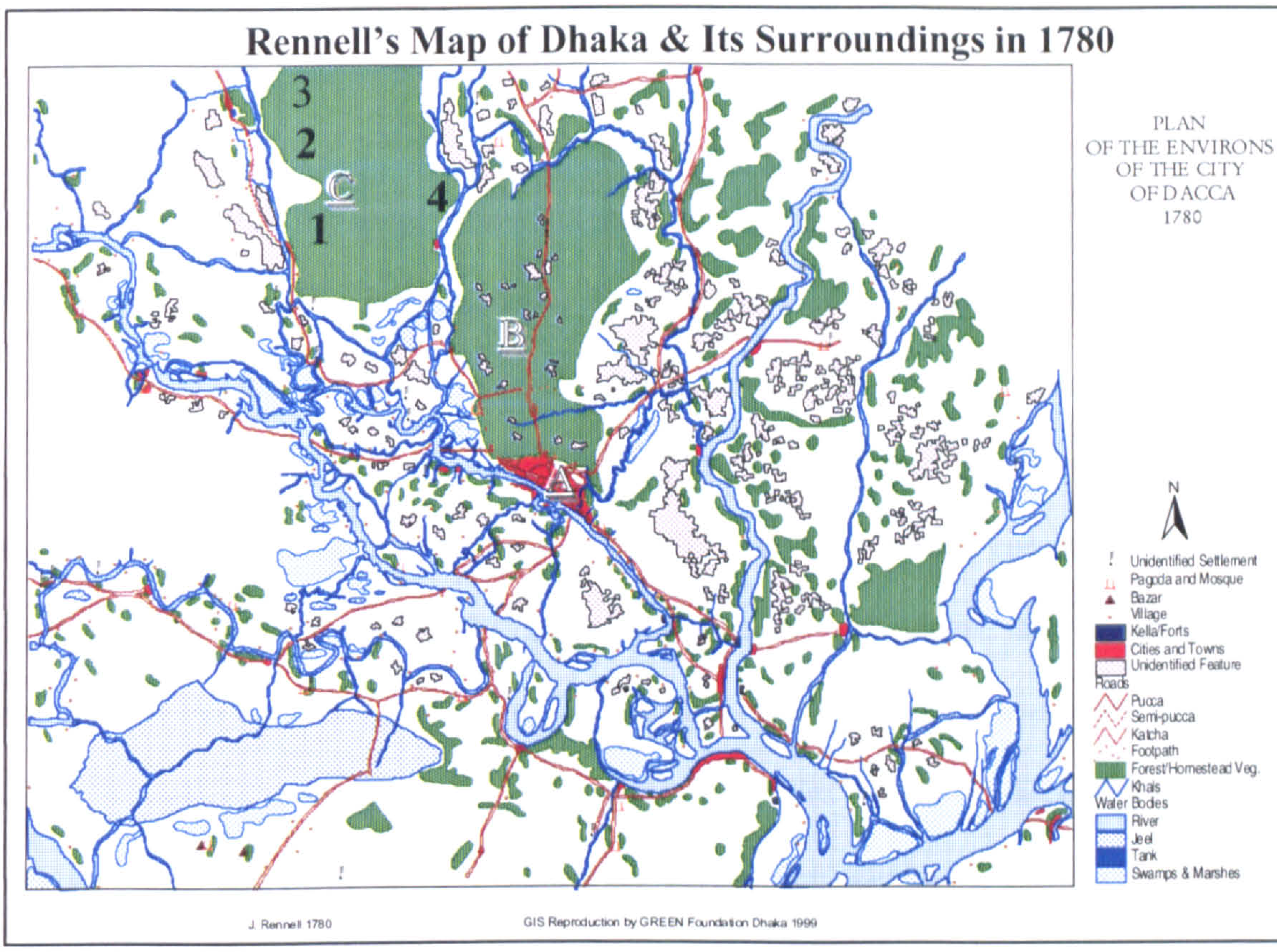


Figure 2-2: Map of Dhaka (former Dacca) was published in 1780 by Major J. Rennell. Location of C indicates the current Savar (former Saabar) *upazila*. *(Courtesy: GREEN Foundation Bangladesh, 1999)*

(e) Topography and Relief

Savar upazila comprises the lands of both the recent floodplain and the Pleistocene terraces, the two major geological units of the deltaic Bengal basin. The average elevation of the area gradually decreases from north to south. The highest elevation is about 20 metres above mean sea level (MSL) and the lowest is about 3 metres. The average altitude is within the range of 10-15 metres. The Pleistocene terrace, that is the *Madhupur* tract in Bangladesh, has a higher elevation and is comprised of elongated and v-shaped/rounded hillocks. Savar is located in the eastern part of the greater Madhupur tract, which is locally known as *Bhawal Gaarh*. The recent floodplains cover the low lying alluvial flat lands and the extended inundated part during the rainy season (Khan, 1995).

(f) Soil Type

Basically there are two varied soil types: those of the Pleistocene uplands and recent alluvial flood plains but some parts are a mixture of both. In general, the northern part of the area is dominated by soil originating from the Madhupur clay formation; whereas the southern portion and across the rivers are characterised by recent soils. As the soils of the floodplains go under floodwater every year, these soils are highly reworked and gain fertility from renewed siltation. They are typically dark, very loosely compacted and have high water content and variable but appreciable quantities of organic matter. In contrast, the soils on the uplands (*gaarh*), that are hardly ever covered by flood-water and have longer periods of exposure to the atmosphere. They are highly oxidised and typically reddish brown and mottled. They commonly contain ferruginous or calcareous nodules. The recent floodplain soils are more fertile for cereal cultivation and seasonal vegetables because of their high water content capacity and rich organic matter, while the terrace soils are the home of the famous and gradually disappearing Shaal forests (*Gozari Baan*) and permanent trees like jack fruit (SRDI, 1992).

(g) Geological Structure and Stratigraphy

Bangladesh is physiographically divisible into three categories: (a) Tertiary hills; (b) Pleistocene terraces and (c) recent floodplains. However, the study area consists of only Pleistocene terraces and recent floodplains. More specifically, it can be considered that the southern study area comprises the Dhaka depression and the northern area is part of the Madhupur uplands. The river Bansi is evidence of the gradual shifting of the Brahmaputra from its ancient course east of Madhupur to its present day course of Jamuna flow. The shifting of the Brahmaputra reflects geological activities in this region. The areas of the recent plains are constantly subsiding, owing to the compaction of recent sediments and possibly to structural downwarp. The Madhupur clay formation is lying unconformably over the Dupitila Sandstones of the Pliocene Age (Table 2-3 and Monsur, 1990 and Alam, 1988).

Table 2-3: A very brief stratigraphic succession of the rocks of the study site

Age	Formation	Lithological Description	Thickness In Metres
Recent	Alluvium	clayey soil, silty soil, earthy grey clay and very fine sand, massive loose and unconsolidated	±3
		Unconformity	
Pleistocene	Madhupur Clay	Reddish brown clay, mottled, well oxidised, ferruginous and calcareous nodules present, compacted	0-31
		Unconformity	
Pliocene to late Miocene	Dupitila	Light grey fine sand together with considerable medium sand at the bottom, loose to moderately compacted	32-65
		Light brown medium to coarse sand, gravels	30-61

Sources: Monsur, 1990 and Alam, 1988

(h) Physiographic Region

The total area of Bangladesh is 144.80 thousand km^2, of which 22.18K km^2 is Hilly land, 30.26K km^2 Terrace Land, 1.22K km^2 is beels and rivers and rest of the land is mainly floodplain, which is the most dominant land feature in the country (Table 2-4).

The physical features of Savar upazila can be classified into three broad categories. These are:

a) *Madhupur Tract*: dominant land types are high, medium high, medium low and very low lands;

b) *Brahmaputra Floodplain*: typical land types are between medium high and very low lands; and

c) *Madhupur Fringe*: usual land types are Medium high, medium low and low lands.

Table 2-4: Major physiographic regions of Bangladesh and the broad land use

Physiography	Area in km^2	Area in Percentage	Dominant land types	Key Land-use
Floodplains	113,370	78.32	Medium High land, Medium Low land, and low lands	Agriculture (mainly Rice and Jute) and Homestead Vegetations
Tertiary Hills	18,172	12.56	Flood free and High land	Mainly Forest, Grassland and Tea Gardens
Pleistocene Terraces	11,971	8.27	High Land and Medium High land	*Shaal* Forest and Agriculture
Beels and Rivers	1,224	0.85	Low Land and Very low land	Fishing and Deepwater rice

Source: Area Calculated from FAO, 1988

(1) Madhupur Tract

This area covers 57 percent area of the total landmass of the Savar upazila. The northern half of Savar upazila is situated in the Madhupur tract. The Madhupur tract spreads over Ward 1, Ward 2, Ward 3, Pathalia, Ashulia, West Biralia, West Yearpur, Dhamsona and east Simulia. Originally this tract was a part of a large Pleistocene terrace within the Bengal Basin with an area of 162 km^2. This elevated land is the result of the tectonic movements to which the Bengal Basin is being subjected. Here, most of the terraces are almost flat in relief, except where the Bansi, Karanatoli and Rangamati Rivers have cut across it. Few *haors/beels* are located here.

The levelling for rice fields has gone a long way towards making the relief uniform. Besides the streams and haor, terraces present a marked elevation because of the entrenched drainage pattern and dissected nature of the tract. These are extensive waterlogged bydes in the south-western parts of Savar upazila, that is the Savar Paurashava (Municipality) area. Ground water is the major source of drinking and irrigation water. Since the 1970s, a few hundred unplanned deep tubewells have been installed here.

According to the inundation conditions, the land can be classified into four further sub-classes: high lands, medium high lands, medium low lands, and very low lands. The total area of low land is negligible. The high land covers more than 50 percent of the total Madhupur Tract region, the actual area is 127.36 km^2. The territory of the other units, medium high land, medium low land and very low land, is 10.20, 14.08 and 9.98 km^2. The dominant soil series of the high lands are Tejgaon, Gerua, Bhatpara, Noadda and the respective areas occupy 72.50, 18.19, 13.81 and 5.49 km^2. In the rest of the area, 17.37 km^2, have been captured by the urban area which is mainly in Savar Paurasava. The soil series of the medium high land are Chandra and Kalma, each of them covering 5.10 km^2. The Khilgaon (14.08 km^2) and Karail (9.98 km^2) soil series are found on the medium high and very low land categories.

The high lands of the broadly dissected terrace areas, being relatively well drained, are mostly used for aus, mesta, mustard, kharif groundnut, sugarcane and cotton. With the support of irrigation, wheat, potatoes and vegetables are extensively grown during the rabi season.

(2) Brahmaputra Flood Plain

This physiographic region is the southern part of the left bank of the lower Brahmaputra floodplain. One third (exactly 30 percent) of the total land mass of Savar upazila is in this flood plain. The lower part of this region is the most backward region of the upazila. All the southern unions, i.e. Kaundia, Amin Bazaar, Bhakurta and Tetuljhora, and the west half of the Simulia and Pathalia unions, are under this land. Only the high/medium high/ medium low lands of this area are comparatively advanced. Here the higher areas are better than the lower, particularly the areas locally known as Chala/Tek. The total area covers 84.78 km^2. The rivers in this region, are the Dhaleshwari, Turag, Karanatoli, Rangamati, Bansi and Buriganga. Except for the Karanatoli and Rangamati, all of which flow around the outer boundaries of Savar upazila. In this physiographic category, three types of land can be identified: medium high, medium low and low lands. 34.22 km^2 of medium low lands are found and these have most potential in this flood plain.

Most of the settlements and seasonal crop lands are located in this region. There are not any large government and semi-government (autonomous) institutions in the Brahmaputra flood plain. Only 19.02 km^2 of low land is found in this area, which is very good agricultural land. The major characteristic of the southern very low land is the location of several large brick fields (locally known as *eater bhata*) in the dry season (in general October to July) and earth moving (locally known as *mattee-kata*) by trucks to meet the existing demand for all types of construction work in Dhaka Metropolitan City. The total area occupied by the lowland is 31.54 km^2, with brick fields covering 18.55 km^2 area. The total riverine area in this floodplain is about 24.82 km^2.

The Brahmaputra flood plain is now active in the southern most unions mostly in the form of char lands which are predominantly raw sandy soils and are seasonally deeply flooded. These areas are mostly used for aus or jute on the relatively higher areas and broadcast aman in the lower areas in the monsoon season. In the dry season, a good portion of the land remains barren, with only sparse grasses used for grazing. The main crops are cheena, kaon, groundnut, water-melon, sweet potato and rabi pulses. Boro paddy is locally grown in depressions using traditional devices of irrigation or low lift pumps, if irrigation water is available nearby.

Non-agricultural land-use is isolated or on small raised platforms (*vita*), often surrounded by banana trees or permanent crops. All of the developing activities receiving low priority in this region are due to its physical barriers and it is also a backward region of Savar upazila in all aspects.

(3) Madhupur Fringe

This area includes the lower valley of the Turag and surrounding areas of Rangamati rivers. Most areas of the Turag valley are seasonally deeply flooded and extensive areas remain wet throughout the dry season. Deep water aman or local boro is the traditional agricultural land use in this area. Capturing fish in the dry season is another important economic activity. This area is a mixed zone where both the Madhupur tract and Brahmaputra flood plain land use are visible.

The Madhupur fringe covers 35.18 km^2 area in Savar upazila (Table 2-5). This long and narrow sub-region follows the course of the Turag, Karanatoli and Rangamati rivers and has a relief of irregular ridges and of depressions. The ridges can be classified as medium high and the depression is very low land. The biggest part of the Madhupur fringe extends over the eastern boundary of Savar upazila. The major agricultural limitations of the Madhupur fringe are rapid permeability, low moisture holding capacity and low soil fertility. The medium highlands of closely dissected areas have high erodibility and steep slopes on the rounded hillocks. These areas are not suitable for large scale irrigation. The main feature of the non-agricultural land use in this area is the rural settlements.

(i) Road Network

The Figure 2-3 has a very important significance. As Savar has no good quality database of roads and water bodies, the map was made in order to overcome this gap. The road network was surveyed with differentially corrected Global Positioning Receivers (DGPS) giving sub-metre accuracy during fieldwork in Bangladesh in 2001 and was verified with high-resolution satellite remote sensing images and aerial photography. The road network has an inverse relation with the lowland and permanent water bodies on this region. In the highlands the density of roads is high, while in the lowlands it is relatively insufficient. The roads in red are part of the government-funded infrastructures and have been restricted against use by the general public. This indicates that the government, in order to develop its infrastructure, has acquired flood free high lands. The water-body data have been generated and digitally classified using supervised classification techniques from the Japanese ADEOS multi-spectral 4-band satellite image of December, 1996 which has a 16-metre resolution. The background water bodies include the rivers, khals, pukurs, perennial lakes and deeply flooded lowlands. The eastern lowland is an obstacle to the connection of Savar with the Capital Dhaka as an integrated urban area.

Table 2-5: The area measured by GIS techniques for each of the Physical Regions of Savar Upazila

Major Physiographic Units			Land Types based on Flood Levels			Dominant Soil Series			
	GIS_id	Area (km^2)	Name	Code	Area (km^2)	Name	GIS_id	Area (km2)	*Mauza Ref
Madhupur Tract	1	161.62	High	5	127.36	Tejgaon	1	72.50	O, K
						Gerua	4	18.19	B
						Bhatpara	5	13.81	O, B
						Noadda	2	5.49	
						Urban Area	18	17.37	
			Medium High	4	10.20	Chandra	3	5.10	
						Kalma	6	5.10	
			Medium Low	3	14.08	Khilgaon	7	14.08	O, B
			Low	2	9.98	Karail	8	9.98	B
Madhupur Fringe	2	35.18	Medium High	4	9.90	Rajashan	9	9.09	G
			Low	2	26.09	Jatrabari	11	19.02	K
						Kajla	10	7.07	K
Brahmaputra Floodplain	3	84.78	Medium High	4	34.22	Melandaha	12	4.43	O
						Melandaha-Dhamrai	13	29.79	O
			Medium Low	3	19.02	Dhamrai	14	7.14	G
						Brahmaputra Sandy	15	11.88	
			Low	2	31.54	Brahmaputra Silty	16	12.99	
						Major Brick-Fields	17	18.55	
			Very Low	1	24.82	Khaler Char (Beels, Rivers)	18	24.82	B
Total Area		281.85			281.85			281.85	

Note for the ***Mauza References** Column: G = **Ganda,** O= **Bara Oalia,** B= **Banshbari,** K = **Bara Kakur**

(Source: Author, 2002)

(j) Rivers and Drainage

The study area is mainly drained by four major streams (*Nodi*): the Dhaleshwari, the Turag, the Bangshi and the Buriganga, and also by two sub-streams (*Khal*): the Karanatoli and Karnapara khals (Figure 2-4). The Dhaleshwari and the Bansi floodplains are drained by a rectangular and trellis drainage pattern. The north western part is drained by the Bansi river and the south western part by the Dhaleshwari river. The Turag flows along the eastern border and the Buriganga flows along the southern border of the *upazila*. Karanatoli *Khal* is located in the north-west most Simulia union. while Karnapara khal connects both the Turag and Dhaleshwari rivers through Savar's eastern edge of the tract.

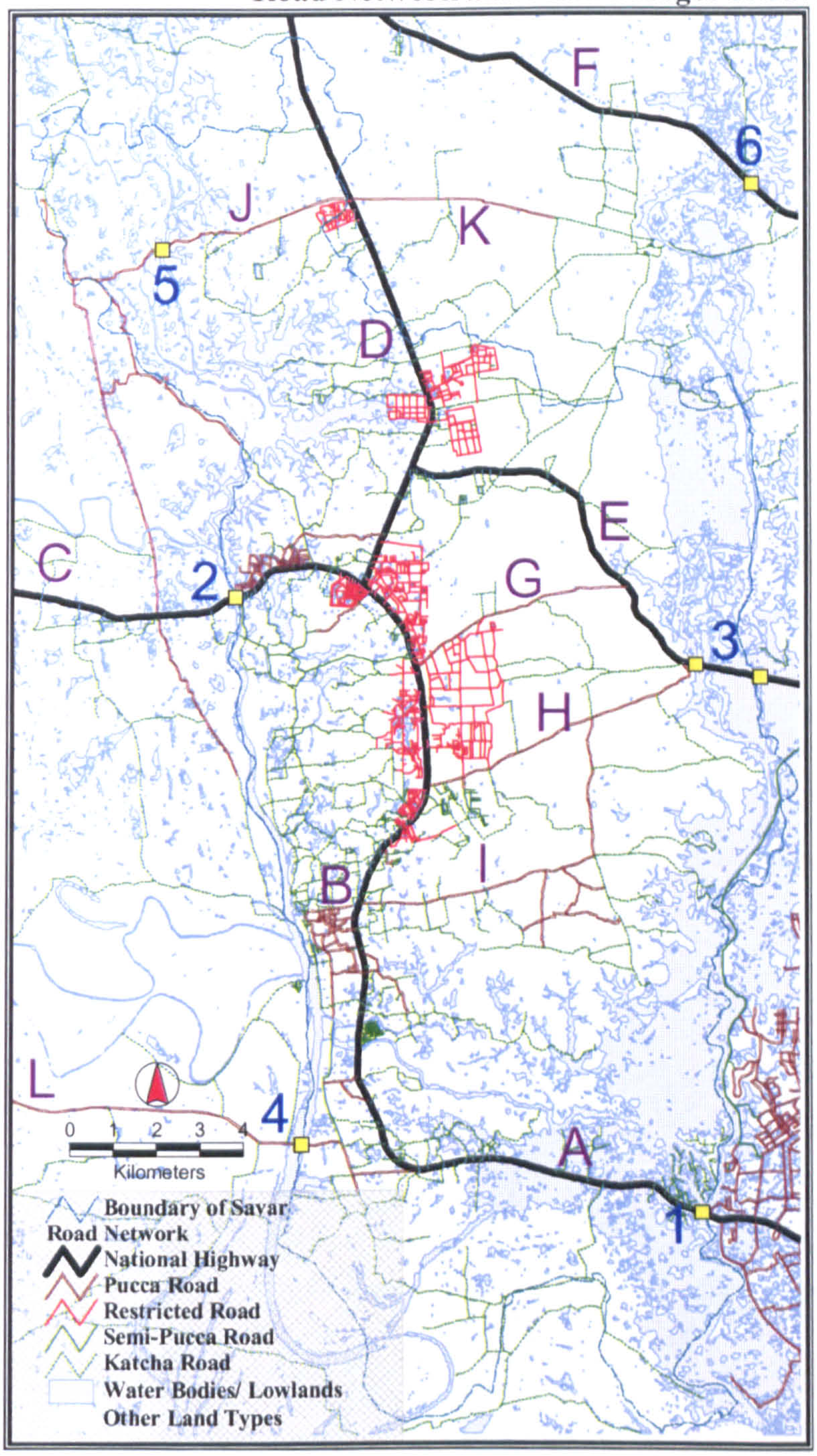
(k) Climatic Conditions

Savar and its surroundings belong to sub-tropical monsoon and humid climatic conditions, characterised by the three distinct seasons (Table 2-6 and Figure 2-5, JICA, 1990):

1. *Garam Kaal* (Summer or Hot seasons): March-May
2. *Barsha Kaal* (Rainy or Monsoon season): June-October
3. *Syeth Kaal* (Winter or Cool season): November-February

(1) *Garam Kaal* (Summer or Hot seasons): This is characterised by high temperatures accompanied by frequent thunderstorms. The maximum temperature ranges from 35°C to 40°C and average temperatures from 20°C to 30°C throughout the year. In the pre-monsoon period, these are sudden storms with wind velocity ranging from 60 to 150 km/hr, known as 'Nor-westers'. Rainfall during these months accounts for about 10% of the annual rainfall. Wind speed varies remarkably throughout the year. In general (excluding wind speed of sudden storms), the highest wind speed is 4-5 knots (1 Knot = 1.852 km/hr). This season is also known as *Prak-Kharif* Period to indicate a certain range of crops.

Road Network and Main Bridges of Savar Upazila



Sources:

DGPS Survey during fieldwork in 2001 and background shows a Supervised Classification of water bodies from ADEOS 1996

Figure 2-3: (Index): A>B>C= Dhaka-Aricha National Highway; D= Nabinagar-Kaliakoir Highway, E= Raptani-Dhaka Highway, F= Kaliakoir-Dhaka Highway. G= Bishmile-Ashulia Feeder Rd; H= C&B-Ashulia Rd; I=Savar-Baralia Rd, J=Jirani-Simulia Rd, K= Jirani-Kashimpur Rd, L= Hemayetpur-Keraniganj Regional Rd. The eastern highways connected Savar Centre (**B**) with Dhaka while other roads connected it with the North and Western regions of Bangladesh. In the late 1960s, A bridge (small yellow box) on Amin-Bazaar depression (**1**) was constructed and for the first time, Savar was connected with Dhaka through road. In 1974 the Nayarhat Bridge (**2**) was built, the road became the busiest part of the national thoroughfare. On Ashulia depression at location **3**, bridges were opened in 1995 by connecting Dhaka through a new frontier. This neglected area of Savar experienced rapid population in-migration without having urban facilities. In 1999, Dhaleshwari Bridge (**4**) connected Savar with Manikganj District directly. Before that a ferry service was engaged to carry vehicles. Simulia union (**5**) was also connected at the same time through road. The bridge (**6**) on the Turag river has always played an important role during flood period since the early 1970s to connect Dhaka with Savar if the Dhaka-Aricha road at section **A** goes under water.

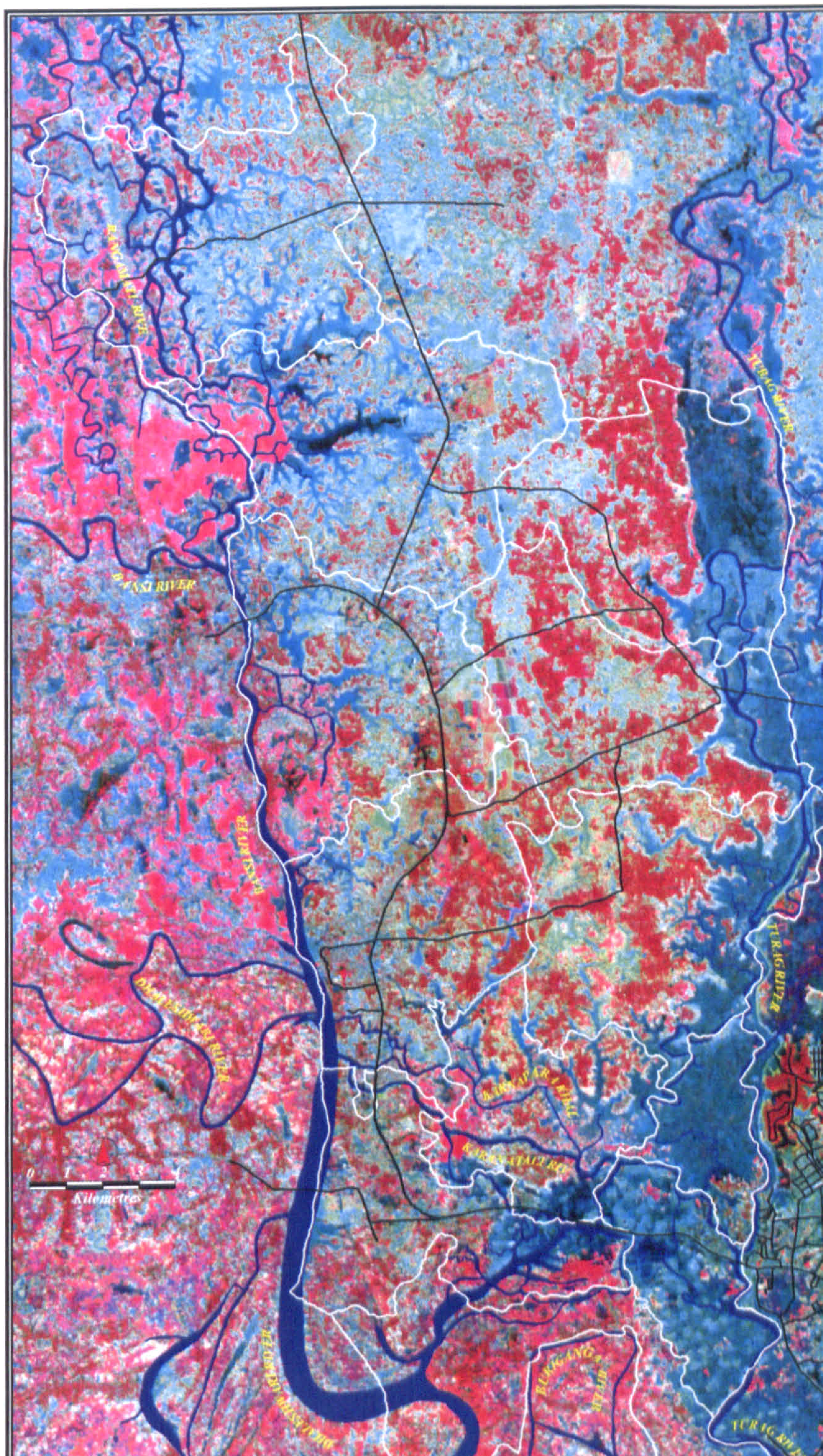


Figure 2-4: On the Landsat TM Jan 10, 1997 (Bands 2-4, FCC) of Savar upazila, a detailed river network is digitised based on high resolution images and DGPS survey. *(Source of River Data: Author, 2002)*

(2) *Barsha Kaal* (Rainy or Monsoon season): Long duration and heavy rainfall, cyclonic storms with destructive winds are frequent during both the early and later stage of the monsoon season. The monsoon rains are mostly not stormy but the rainfall can amount to 50mm to 75 mm per day occasionally. Rainfall during this period is about 90 percent of the annual precipitation, that is approximately 2,000mm. Maximum rains fall in the months of June and July. During the monsoon, the relative humidity ranges between 85-90 percent. Maximum temperatures are relatively low in comparison to *Garam Kaal* due to the presence of extensive cloud cover during this period. Agriculturally speaking, this is the *Kharif* period.

(3) *Syeth Kaal* (Winter or Cool season): It is characterised by dry and foggy weather conditions and very rare rainfall events. The evaporation rate is lowest in November. The average temperature varies from 15°C to 20°C in December and January with the lowest temperature about 4-6°C. The lowest wind speed of the year is recorded during November and December, at about 1-2 Knots. To indicate the wide range of dry season crops, this season also known as *Rabi* period.

Table 2-6: The basic climatic data of Savar based on local seasons

Cropping Seasons	Prak-Kharif (Hot Summer)			Kharif (Monsoon or Rainy Season)					Rabi (Dry Winter)			
Months	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Highest Temp °C	40.6	42.3	40.6	38.4	35.2	35.9	35.3	38.8	33.3	31.2	34.2	36.6
Lowest Temp °C	10.4	15.6	18.4	20.4	21.7	21.0	22.0	10.4	10.6	6.7	5.6	4.5
Average Temp °C	26.4	28.7	28.9	28.7	28.7	28.7	28.7	27.4	23.6	19.8	18.8	21.5
Average Rainfall mm	52.3	124.0	283.0	398.2	391.4	328.0	264.0	160.0	25.2	7.4	6.5	20.2
Relative Humidity %	63	71	79	86	87	86	86	81	75	74	70	66
Evaporation mm	81	77	78	83	87	130	118	106	75	105	104	79
Days of Rain per month	4	8	14	19	22	22	16	9	2	1	1	2
Wind Velocity (knot)	3	5	5	4	4	4	3	2	1	1	2	2

Source: Data compiled and integrated from FAP-8A 1991 and SRDI 1995 *(l) Seasonal Diversity*

Land Types are basically linked with the depth of flooding and kinds of crops suitable to be grown. A revised and modified version of the Master Plan Organization for planning national water resources use is found in Table 2-7. This has been elaborated in Table 2-8 in order to understand the seasonal diversity of Savar upazila. Figures 2-6 to 2-8 based on seasonal Landsat images give a very interesting picture of the land.

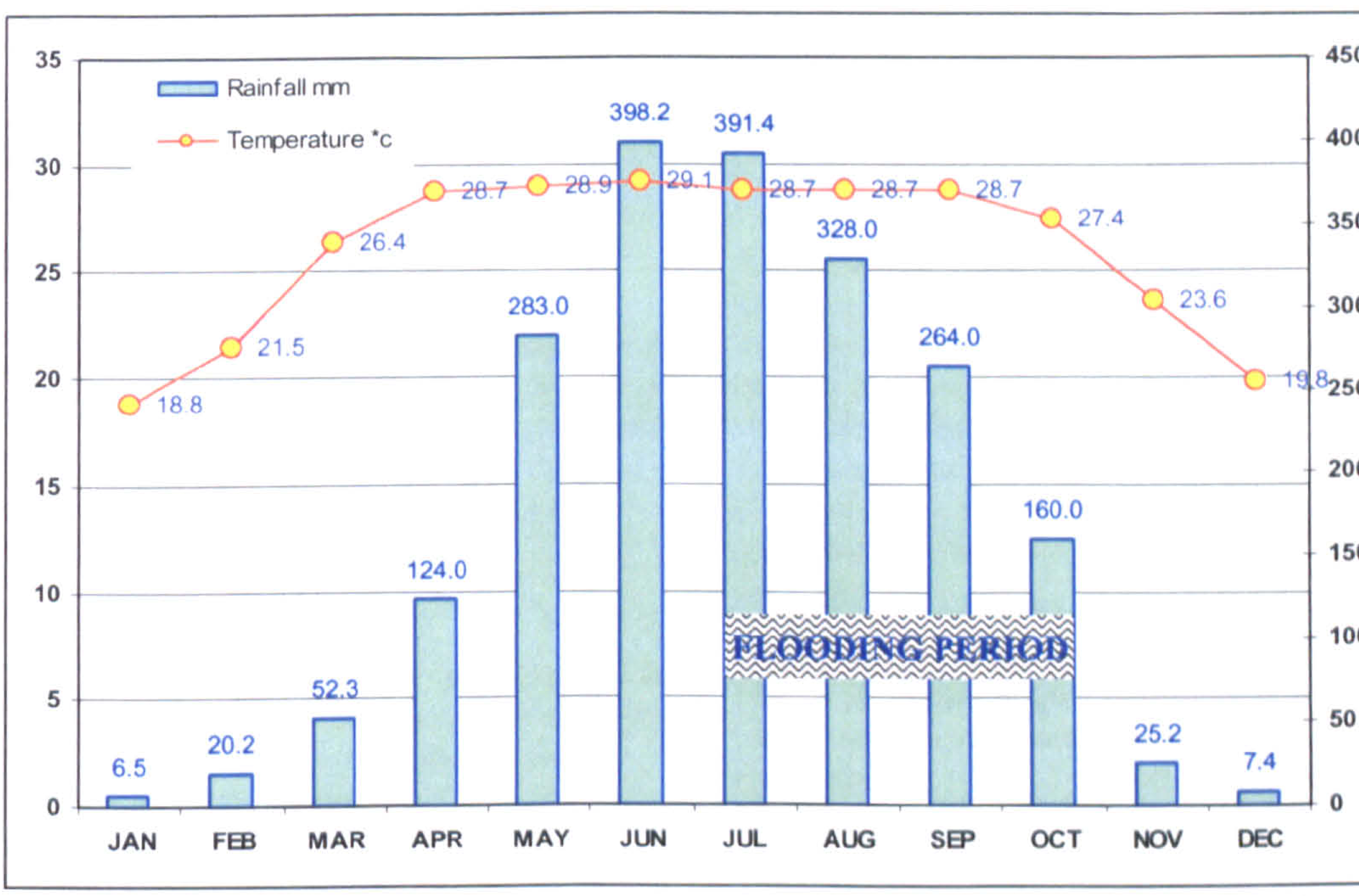


Figure 2-5: The above statistics of Rainfall and Temperature of Savar upazila are reflections of the very dry & mild winter (Nov-February), relatively dry & cloudless summer (March-May) and rainy, clouded & humid Monsoon (June-October). But the main flooding period builds momentum (July-October) when the massive upstream water comes from the Himalayan Ranges with its peak capacity and the ground becomes completely saturated despite the significant reduction of rainfall.

Table 2-7: The land types of Savar *upazila* using FAO Codes with their basic characteristics.

FAO Code	Land Type	Depth & duration	Nature of Flooding	Usage in Savar*
F0	High Land	0-30 cm, for a few days	Intermittent	Suited to HYV rice in wet season with irrigation, transplanted Aus/Aman, Vegetables in Dry Season, Shaal Forest, Perennial trees
F1	Medium Highland	39-90 cm	Seasonal	Local Varieties of Aus and T. Aman, Jute
F2	Medium Lowland	90-180 cm	Seasonal	B. Aman in wet season
F3	Low Land	>180 cm	Seasonal	Land on which B. Aman can be grown in wet season
F4	Low to very low Land	>180 cm	Perennial/ Semi-Perennial	Occasionally Deep Water Aman to be grown depending on the other factors like timing, depth or increasing rate of flood water.

*Source: Modifications based on MPO, 1986 and *Fieldwork 2001.*

Table 2-8: General (FAO) Land types of Savar *upazila* and their current use

Land type	Nature of Flooding	Criteria	Agricultural Land use	Non-agriculture Land use
High Land (**F0**-Chala)	Intermittent	Normally non-flooded and rainwater cannot be retained on the surface. In few cases rainwater can be retained on the surface for a while.	Annual and perennial dry land crops such as sugarcane, pineapples, banana, fruit trees (Remarkable fruit tree is Jack fruit), field crops such as maize, groundnut, cowpeas, vegetable etc.	All major infrastructures /institutions, industrial estates and municipal settlements of Savar upazila are located on this land.
Medium High (**F1**-Tek)	Seasonal	Normally inundated less than 30 cm deep (very shallowly flooded, may be for 2-3 weeks)	Mainly temporary crops (one crops in a year) and few fruit trees.	Some of the large infrastructures and the urban / semi-urban settlements are located here.
Medium Low (**F2**-Tek /Dhala)	Seasonal	Normally inundated in the range of 90-180 cm. (shallowly flooded)	Mainly temporary crops (two crops in a year) and	Most of the rural settlements are located here.
Low (**F3**-Byde)	Seasonal	Normally inundated in the range of 180-300 cm (deeply flooded)	Broadcast aman or boro	Some of the seasonal settlements
Very Low (**F4**-Nama, beel)	Perennial/ Semi-Perennial	Normally inundated more than 300 cm deep (very deeply flooded)	Deep water Aman or floating aman or boro	No settlements /infrastructures

Source: Based on fieldwork 2001

Landsat TM Encapsulated Seasonal Diversity of Savar

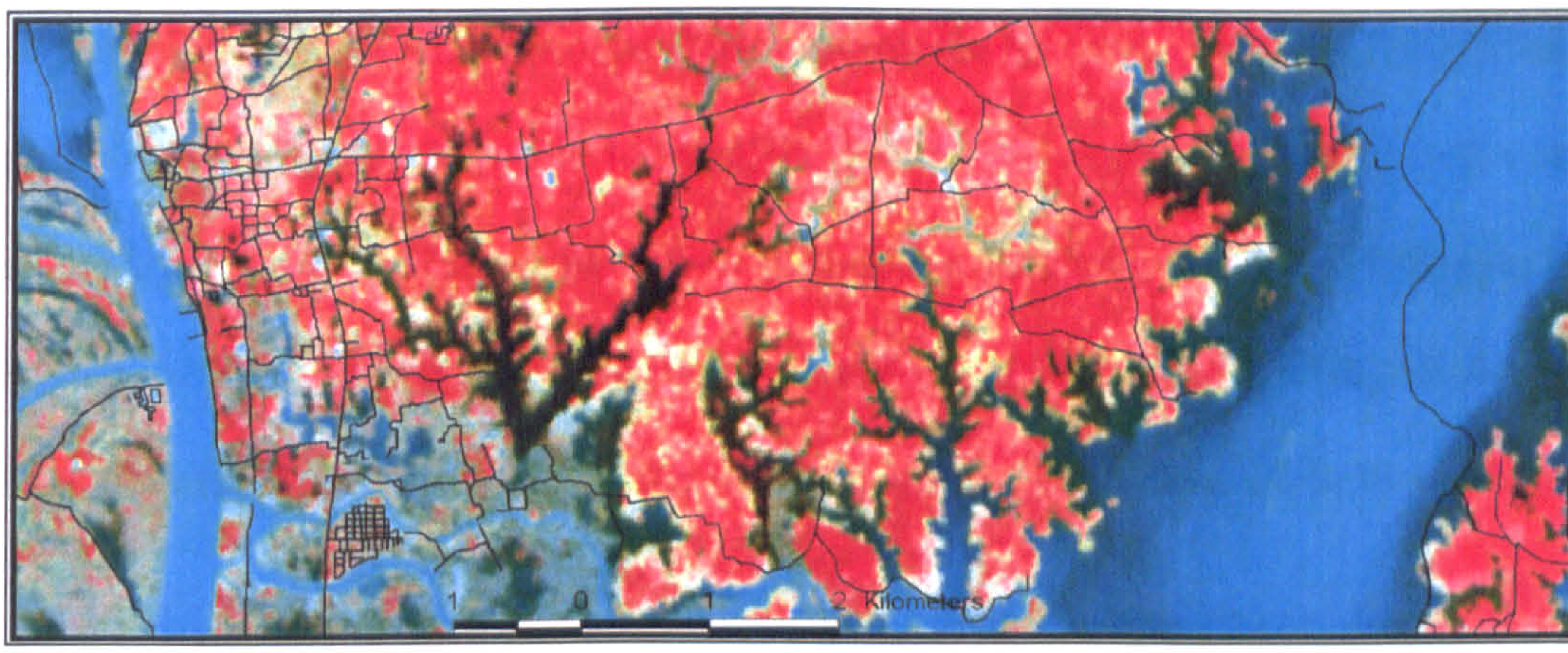


Figure 2-6: Kharif Crop Season (Jun-Oct): All non-*chala* agricultural fields (F2-F4) are inundated by monsoon prolonged (about half a year) flood water. Only high (*chala*) lands are confined for cropping practices and look like islands from space (source: Processed image of Landsat TM, Oct 1988).

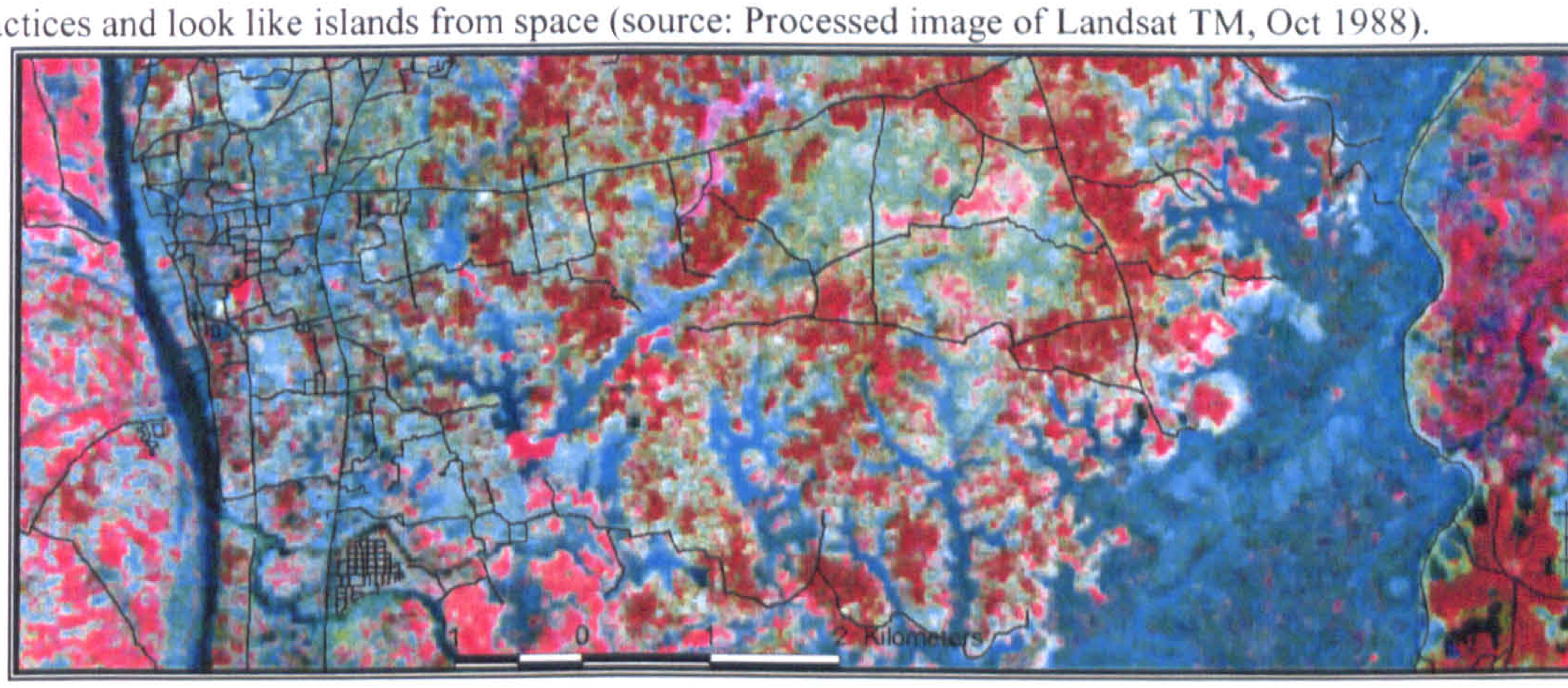


Figure 2-7: Rabi Crop Season (Nov-Feb): The water has receded recently from the low lands and no crops are there or they are at a very early stage. The perennial trees (red tone) are clearly visible due to their high ratio of chlorophyll content in the leaves (source: Processed frame of Landsat TM, Dec 1996).

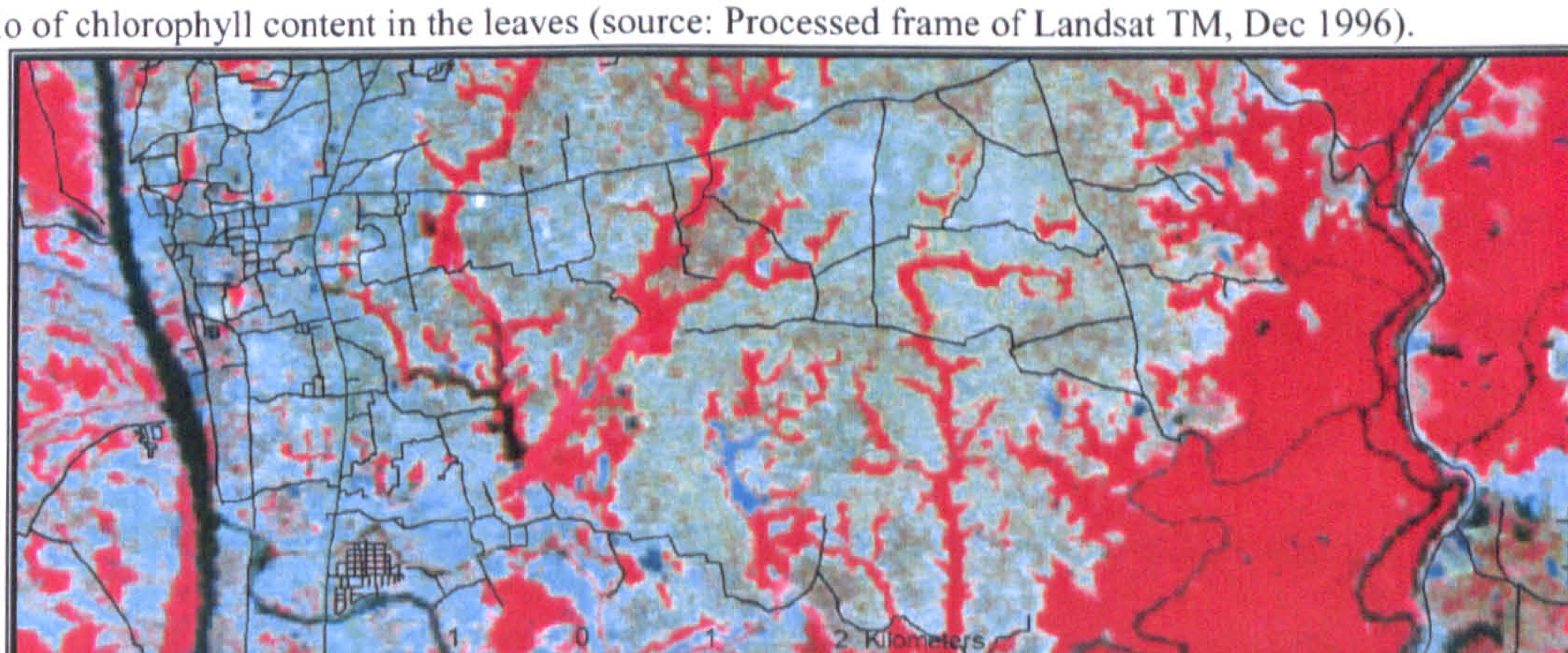
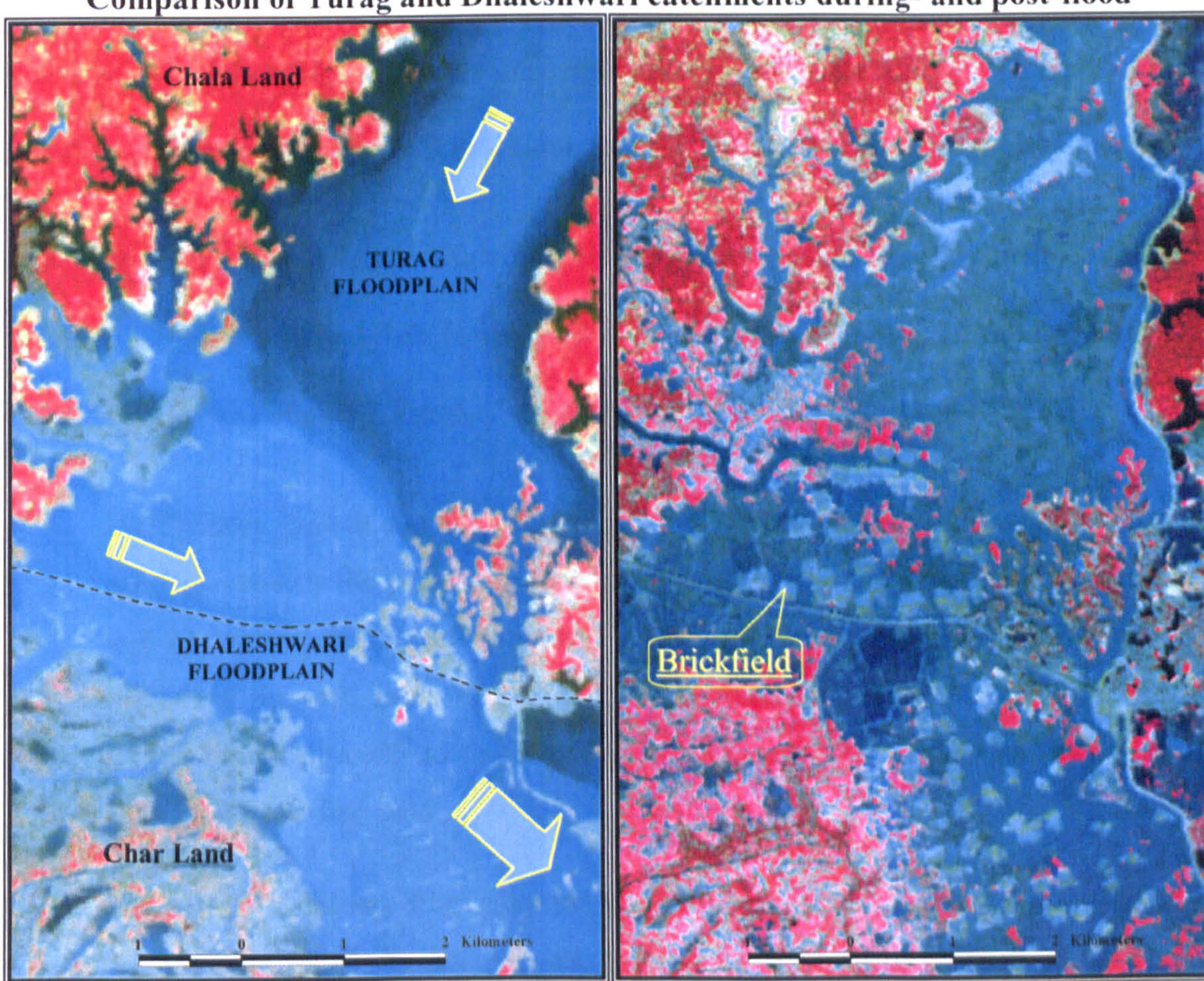


Figure 2-8: Prak-kharif Crop Season (Mar-May): The recycled fertile non-chala lands after receding of flood water are fully embraced with seasonal aus paddy and other grain crops, the highland perennial trees are at the end of their decidual phase in the late winter (source: Processed frame of Landsat TM, April 1999).

(m) Underwater Economy: An Example

Rivers contain massive amounts of sediment during the monsoon floods in Bangladesh but the load-intensity depends on the form of the floodplain, as reflected in the **left** Landsat image (Figure 2-9). The Turag basin is a part of the Pleistocene terrain (as stable *chala* land) and the Dhaleshwari floodplain is the part of the active delta (as a fragile *char* land). These have different and distinctive spectral signatures when they meet in the common Amin-Bazaar depression (*chwak*). The Dhaleshwari's water is opaque because it contains heavy load of sediments and has a strong current as a reflection its devastating impact along its channels specially in the upstream, whereas the Turag contains relatively fine and light sediments, with almost (semi-) transparent water and there is little or no erosion of the adjacent land. As a result, unlike the entrenched and narrow Turag River, the meandering and wide Dhaleshwari channels still threaten villages and fields. The image also defines the confined territory of the confluence of the both rivers and limits their jurisdiction of the commonly shared depression zone though having no physical barrier. The entire national highway (dashed line in the left image) was still under water, though the Landsat image was taken a few weeks after the peak flood-level in Savar and its neighbouring regions. The arrows show the direction of river flow in general. By contrast, the **right** ADEOS image shows the same area after the recession of the floodwater. The Dhaleshwari floodplain is being used here as the biggest zone of Brick-fields around the capital Dhaka. The brickfield activities are limited to the dry period, at most seven months. Thousands of seasonal labourers (both males and females) usually migrate into this area to find low-paid jobs (About £1 per 12 hours) on a casual daily basis. Each brickfield the local clay dominated soils as their raw material, with the result that the land surface is gradually downward. Interestingly this is replenished each year as shown in the left frame of Figure 2-9. A massive amount of sediment-load is carried annually from upstream to Bangladesh, the biggest delta in the world, through her hundreds of rivers. If all of this sediment could be stored, it would create a new landmass the size of Sri Lanka within only five years! The sediment load could be calculated and classified using multi-spectral data if a proper methodology could be devised, although that is beyond the scope of the present research.

Comparison of Turag and Dhaleshwari catchments during- and post-flood



Source: Processed clips of Landsat TM October 1988(left) and ADEOS December 1996 (right)

Figure 2-9: Dhaleshwari Floodplain with (left) and without (right) flood water near Amin Bazaar Union. The local land emerges from boat economy to brickfield economy. The total pictures of the dry and wet seasons are completely reversed.

(n) Rajuk Master Plan: 1995-2015

Dhaka Metropolitan Development Plan (DMDP) 1995-2015 has been prepared by Rajuk, approved by the government of Bangladesh (SRO No. 184-law/97 dated: 3-8-1997), and published in the Bangladesh Gazette on August 4, 1997. So the DMDP plan is a part of the law and all relevant bodies of the Government and Non-government have been obliged to abide by the law since then. The plan has two volumes: volume one is on Dhaka Structure Plan (1995-2015) and Volume two focused on Urban Area Plan (1995-2005). The plan was funded by various donor agencies including the UNDP (United Nations Development Programme), the World Bank and the ADB (Asian Development Bank).

According to the Rajuk Plan, Savar can be described on the basis of their evaluation criteria: (*Dispersed Flood-free Development Areas: Dhaka Metropolitan Development Plan (1995-2015) Volume -I, Dhaka Structure Plan 1995-2015 page 39-40*):

> "With most growth having been focused on Dhaka's main urbanised area and directed towards the priority project areas within the areas protected by FAP (8A and 8B) during the DMDP structure Plan period to 2015, there may be a case for reviewing options, prior to the end of the planned period, to divert some of Dhaka's future growth to more dispersed locations which have the advantage of relatively flood-free land.
>
> The DMDP Structure Plan acknowledges that planned dispersal of population to new or satellite towns has proved, throughout the world, to be a costly and a drawn-out process. Rarely if ever do they address the shelter needs of the urban poor or create sufficient job opportunities to sustain their livelihoods, without massive subsidies. In most developing countries where these policies have been pursued, they have been proved to be totally inappropriate. They have also been expensive to maintain and administer and a drain on scarce national resources. For these reasons, the DMDP Structure Plan's strategy for dispersal is that the priority locations in metropolitan Dhaka are those which benefit from elements which

optimise resource expenditure, minimise development costs and, most importantly, act as a catalyst for appropriate and affordable development. The key elements of this strategy are:

- Use of relatively high, flood-free land;
- minimal conflict with high quality agricultural land;
- existing transport links to Dhaka city and between the location and other regional centres;
- use of an existing core settlement or settlements;
- the vestige of an existing urban economic base;
- ease of infrastructure provision, particularly water and electricity;
- relatively low land costs affording secure tenure rights;
- Impetus of current development trends.

On the basis of these criteria, there are only two locations in the DMDP Stucture Plan area which rank for consideration in the planned period to 2015. This is an area of Savar and north in the extreme north-west of Rajuk's control area, referred to as Dhamsona, after a village in the vicinity (and the area of Tongi and northwards to Gazipur.) These areas already boast a large employment base deriving from recent relocation initiatives of both the private and public sector, of which the new Export Processing Zone (EPZ) is the largest and most recent."

This is the first time that Savar upazila has been under any long term planning programme in its history, and it is now included in the master plan of Dhaka under Rajuk's jurisdiction. That means that it is now physically part of the Capital city. In the plan, Savar has been classified into three categories, as Strategic Planning Zone (SPZ) 17-1 (includes Savar Union and Paurashava), SPZ 17-2 (mostly Dhamsona and Pathalia Union) and SPZ 17-3 (the rest of the upazila excluding Simulia Union). Brief descriptions of the each zone are given (see Figure 2-13) below. It is to be noted here that 7 north-western mauzas of

Dhamsona (8.87 km^2) and entire the Simulia union with 25 mauzas (35.12 km^2) is located outside the Rajuk boundary, so this part of the upazila has not been considered in the SPZ classification. In all cases of Boundary demarcation, Rajuk has used mauza boundary as the lowest unit of development and planning cell and they try to keep also the integrity of the union boundary.

(1) SPZ 17-1: Paurashava Dominated Zone

This zone (Figure 2-10) has been described in the report as a largely flood-free zone, experiencing substantial rural-urban conversion which includes: a paurashava, all of the upazila head quarters, a university and a PATC. Much of the roadside land is occupied by the government dairy farm, agricultural projects initiated in the early 1960s, which could be relocated. A detailed area plan is required. In this zone a total of 51 mauzas are located with an area of 26.67 km^2 (calculated using GIS methods).

Figure 2-10: Massive investment and construction works has been going on since the late 1980s in Savar Paurashava (part of SPZ 17-1) without any planning obligations. I can term SPZ 17-1 zone as the administrative capital of the upazila.

(2) SPZ 17-2: Development Potential Zone

In the report, Dhamsona Zone (including most of the Dhamsona and all of Pathalia Unions) is recognised in the structure plan as having a high long term development potential (Figure 2-11) and its development should be enabled. Important features of the area are the EPZ, the national mausoleum, the Atomic Energy Centre, and the Savar Cantonment. The area is connected with two highways: Dhaka-Aricha and Tangail-Savar. The restricted zones are less attractive for development. The newly constructed Tongi-Ashulia-EPZ road provides the area with an alternative connection with the Dhaka city. A detailed area plan is required. A separate municipality could perhaps be created to provide the guidance to public and private development. The total area is 52.70 km^2, which includes 41 mauzas. The SPZ 17-2 can be termed as the industrial capital of the upazila.

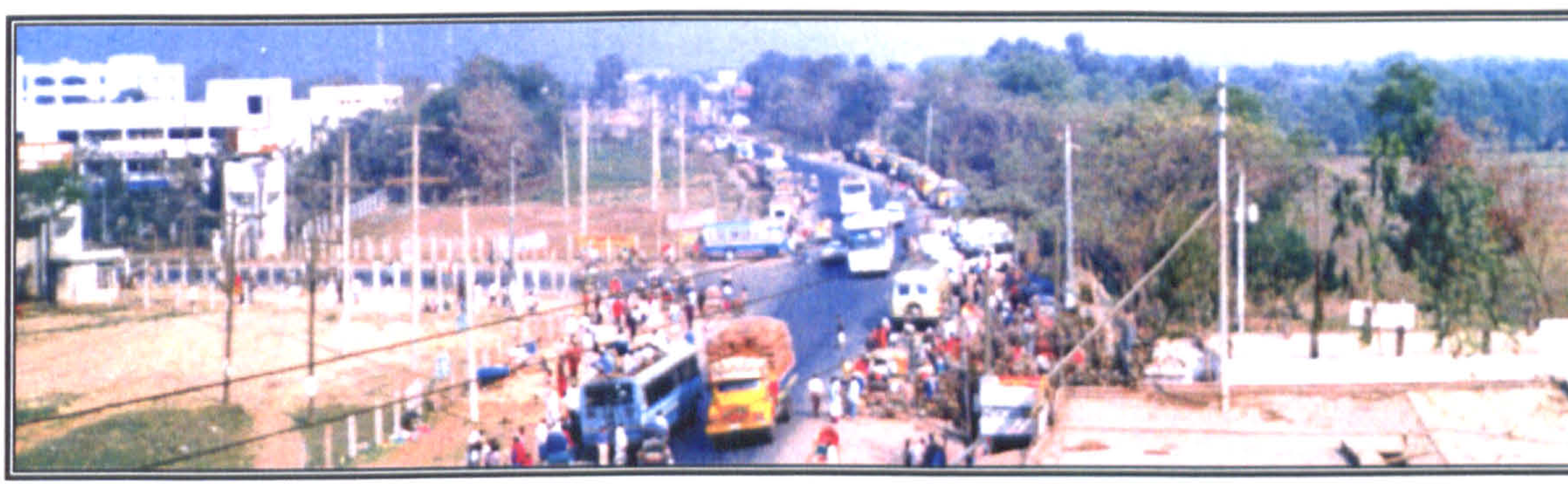


Figure 2-11: The SPZ 17-2 can be termed as the industrial capital of the upazila. There is a vast open area which is yet to be developed and a vary detail plan is immediately required as mentioned in the Rajuk Master Plan.

(3) SPZ 17-3: Strictly Agriculture and Pisciculture Zone

This zone, as specified in the Master Plan, is a low-lying area cut across by Turag and its Khals and is designated as flood plain and should function as a rural, agriculture and pisciculture zone (Figure 2-12). According to the proposed plan, all development should be discouraged to enable the free flow of flood water. Also, permits already issued for development of housing should be withdrawn and the conversion of land from rural to urban land use should be strictly regulated in this zone. The zone will provide a buffer between the central core (Dhaka Urban Area) and the emerging satellite zone (Paurashava, Pathalia and Dhamsona Unions), thus providing much needed open spaces. This is the biggest strategic planning zone, with an area of 161.08 km^2 and 150 mauzas.

Figure 2-12: Flood-prone SPZ 17-3 of Turag Basin has been recommended by Rajuk as a protected zone of agricultural and pisciculture so that the increasing demand for vegetables and fish of the adjoining urban areas can be met and the zone can remain a ruralised buffer between the capital and the Savar urban area.

It is mentioned in the report that in "mid-1999, the first of series of a DMDP structure plan reviews and update will be undertaken". It is also recommended that the plan will be reviewed in every five years in 2005, 2010, until 2015.

An overall map of the three sub-zones of SPZ 17 is given in Figure 2-13, where the relative location of Savar upazila is shown and there is an outline of the spatial distribution of the Dhaka urbanised area. Also, the proposed future highways of the Rajuk area are presented with the proposed five satellite towns.

There is also a discussion about the agricultural land of Savar upazila. It is mentioned in the plan that approximately one-fifth of the land within the DMDP Structure Plan area has been evaluated as good to very good agricultural land. The urban population is expected to double in the plan period up to 2015; the demand of agricultural products will predictably rise, resulting in greater demand for fresh fruit and vegetables. Ideally, and for reasons of cost efficiency, these demands would be best met from market gardening areas within close proximity of the city. So areas of high quality agricultural land within the market catchment area of Dhaka will be conserved and promoted as areas of intensive food production.

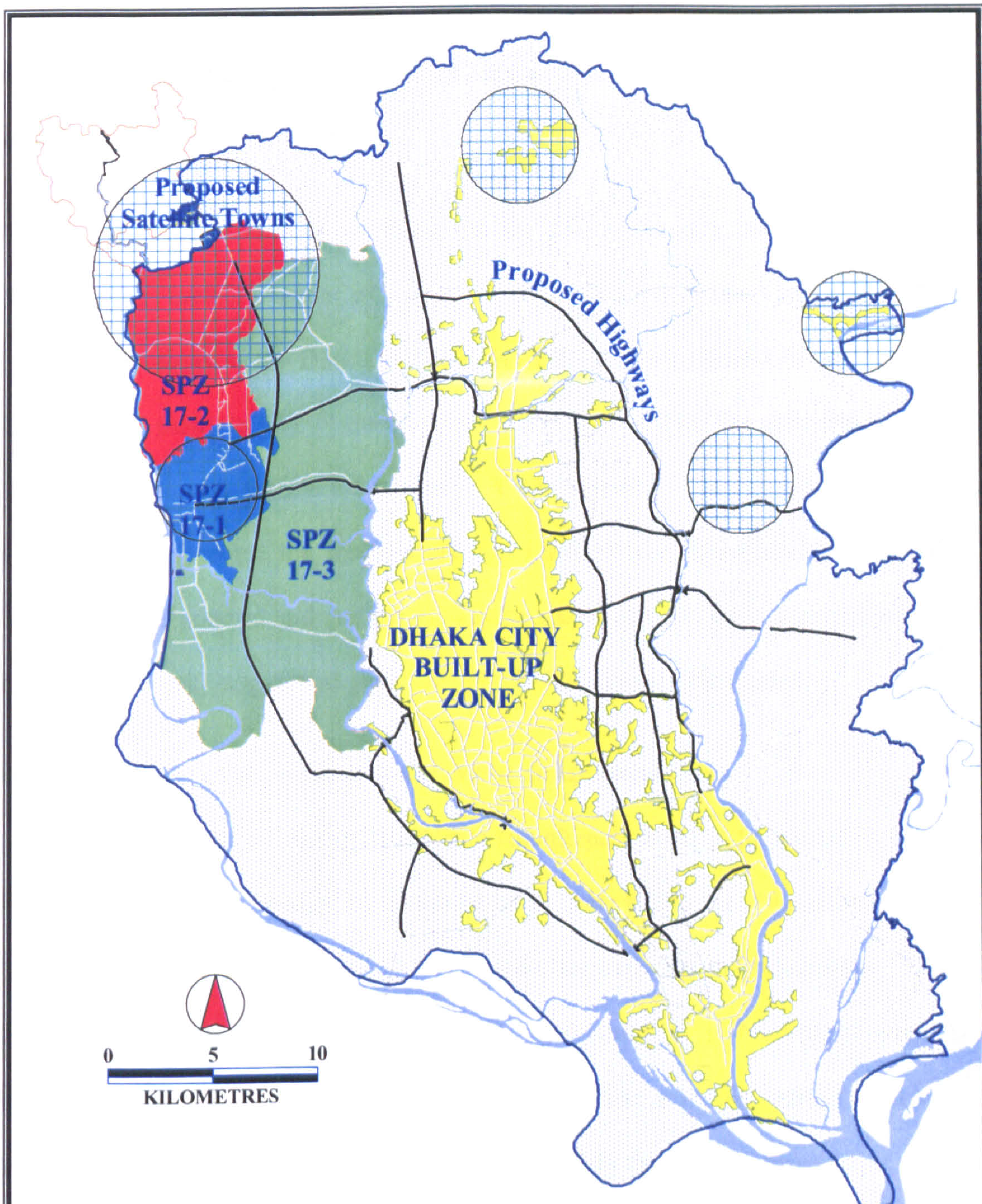


Figure 2-13: The Rajuk Jurisdiction map shows the three Strategic Planning sub-Zones (SPZ 17-1, 17-2 and 17-3) of Savar upazila and the locations of built-up areas of the capital city of Dhaka with a proposal of 5 circled satellite towns, two of them, including the biggest one, are in Savar upazila. These are: Paurashava and Dhamsona (map compiled from: Rajuk, 1997 and Author, 2002).

In subzone, SPZ 17-3 there will be restricted development of existing village clusters. Here, structures will not be more than two stories and uses must be ancillary to and supportive of the agriculture sector. The Metropolitan Development Planning Authority, Rajuk and Thana/upazila Authorities will implement the above obligations in order to protect agricultural land.

Tender for Detail Urban Area Plan: On the 15th of January 2001, Rajuk (Director, Town Planner) invited a tender with terms of reference for a detailed area plan (DAP) for a total of 15 blocks of the DMDP area (Rajuk, 2001). Block number 15 refers mostly to SPZ 17-3 and partly to 17-2 of the Savar upazila (Figure 2-14). The main objective of the DAP was to 'provide a basic urban design of good quality'. They recommended that the policy should represent the recommendation made in the Structure Plan (1995-2015) urban area plan policies and guidelines. The proposal of a tender is highly controversial due to a clash with the gazetted guidelines of 1997, as already mentioned.

(o) Third Urban Development Project (1999): Savar Paurashava

I can say simply that the Savar Paurashava (municipal) is the Administrative Capital of Savar upazila and is controlled by an autonomous body called the 'Paurashava Parishad". The head of the Parishad (council) is an elected Chairman (since 7th December 1994). On December 12, 1991 it was upgraded from Savar Union to a Paurashava (memo ref: SRO/349/91, date:13-11-1991, Ministry of LGRD[1]). The activities started of this newly declared municipality on March 16, 1992. In 1997 (July the 5th), Paurashava got first class status and there is a possibility of declaring it as a "special class" very soon. The Paurashava is also part of Third Urban Development Project (TUDP), which embraces twenty two secondary towns in Bangladesh. The central theme of the TUDP was to assist

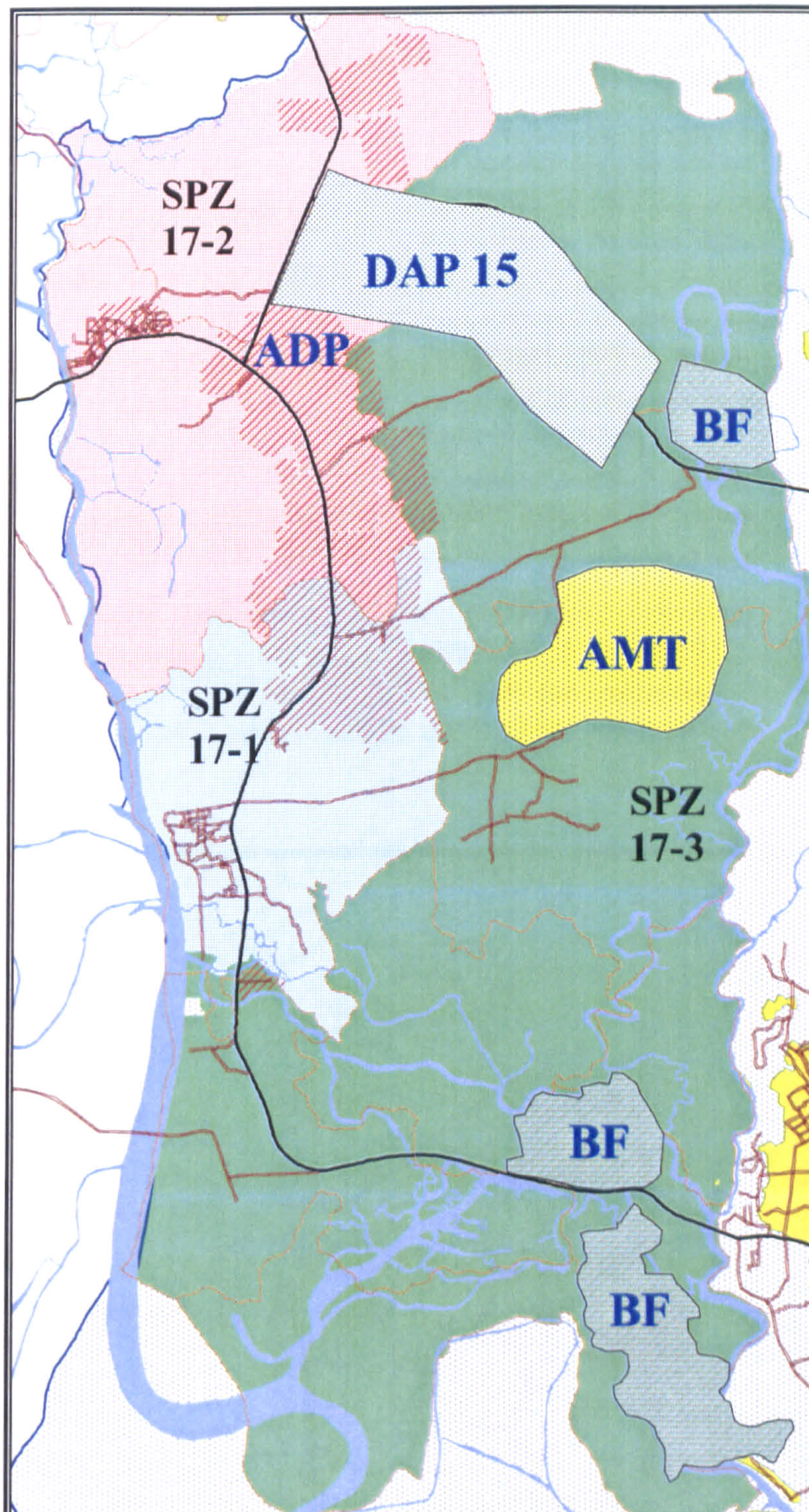
[1] Local Government and Rural Development of Bangladesh

the economic development of secondary towns to reduce the rural migration to the Metropolitan cities (ADB, 1999). In achieving this goal three major elements are identified: the economic potential of the town, the living environment and the local government. A detailed land use plan has been presented in the report for Savar upazila. In August 1997, the Rajuk master plan was published and in October 1997, the ADB signed an agreement for the full development of Savar upazila in order to achieve: improved urban productivity; increased access to improved service and sustainability in the delivery of services by urban dwellers including poor. Detailed land use, existing and proposed roads and drainage systems have been mapped (Figure 2-15).

However, most remarkably, the TUDP does not mention the Rajuk master plan (Figure 2-16) and its review or the accountability regarding SPZ 17-1 in terms of coordination between two plans despite the fact that the TUDP was started a few months after the final approval of the Rajuk master plan. Both of the plans were partly funded or represented by the ADB.

2.3.0. Availability of Data and Images

Before starting the detailed discussion of data and images, it is reasonable to give a general idea how the following chapters will be based on the information in Table 2-9.



INDEX

DAP 15 =
Detailed Area Plan for Block 15 (Rajuk Invited Tender on 15-01-2001)

SPZ =
Strategic Planning Zones (Demarcated By the Rajuk Master Plan 1995-2015 as zone **17**)

17-1 =
Paurashava Area (ADP Planned Zone)

17-2 =
Proposed Urban Area (Rajuk's proposal of biggest Satellite Town)

17-3 =
Restricted Urban Zone (should be used for Agriculture and Pisciculture)

ADP =
Already Developed Parts (University, Cantonment, EPZ, Monument etc)

AMT =
Ashulia Model Town (Private Sector Biggest Housing Project)

BF =
Brickfields (Old Amin Bazaar and newly Ashulia (north) Belts)

Figure 2-14: The locations of Strategic Zones have been illustrated with the concerned elements conflicting the Rajuk Master Plan. For instance, Ashulia Model Town should not be here if you respect the plan and Rajuk itself have been violated by inviting a tender of detail urban area plan falling mostly into the SPZ 17-3.

Table 2-9: Major Data and Maps relevant to the chapters

Main Data/Image Types	Main Reasons	Chapter/s Concerned
Landsat and ADEOS	To make familiar of the Study Area using multi-spectral images	Mainly Chapter 1 and 2
Upazila/Union Maps	For upazila level study and to understand the context	Chapters 2, 4, and 5.
Planning Maps and some discussion	For evaluating Planning Matters	Chapters 2 and Appendix A
IRS-1D Maps and Aerial Photos	To verify IRS-1D with the Aerial Photos and CORONA images.	Mainly Chapter 3 and 4
CORONA Films	To verify CORONA data for the first time in Bangladesh	All chapters but mainly Chapters 3, 4 and 6
Census Data	Population trend analysis and enhancing them with RS images	Mainly Chapters 4 and 5
Mauza Maps at Plot Level	For the plot level detailed study	Mainly Chapter 6
Field Data and Information	For verifying and interpreting images and secondary data	All Chapters but mainly Chapter 3 and 6
DGPS data	For road maps, mauza maps geocorrections and projections	All Maps and Images in the thesis

Source: Author, 2003

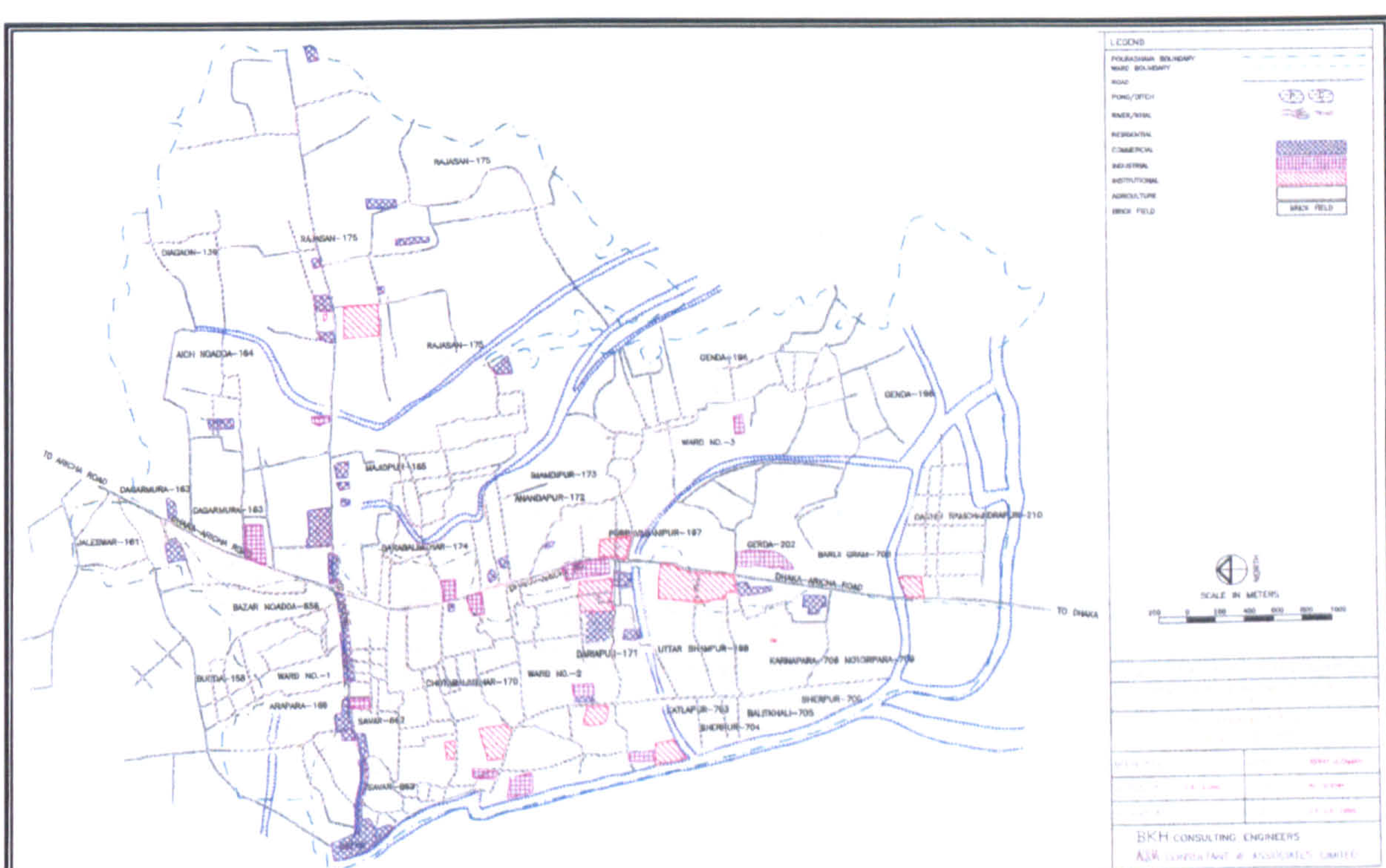


Figure 2-15: Savar Paurashava Plan funded by the Asian Development Bank (ADB) in 1998 as a Third Urban Development Project (TA No. 2816-BAN) and prepared by the BKH Consulting Engineers (Netherlands) in Association with Aqua Consultants and Associates Limited (Bangladesh) under the supervision of LGED, has raised confusion.

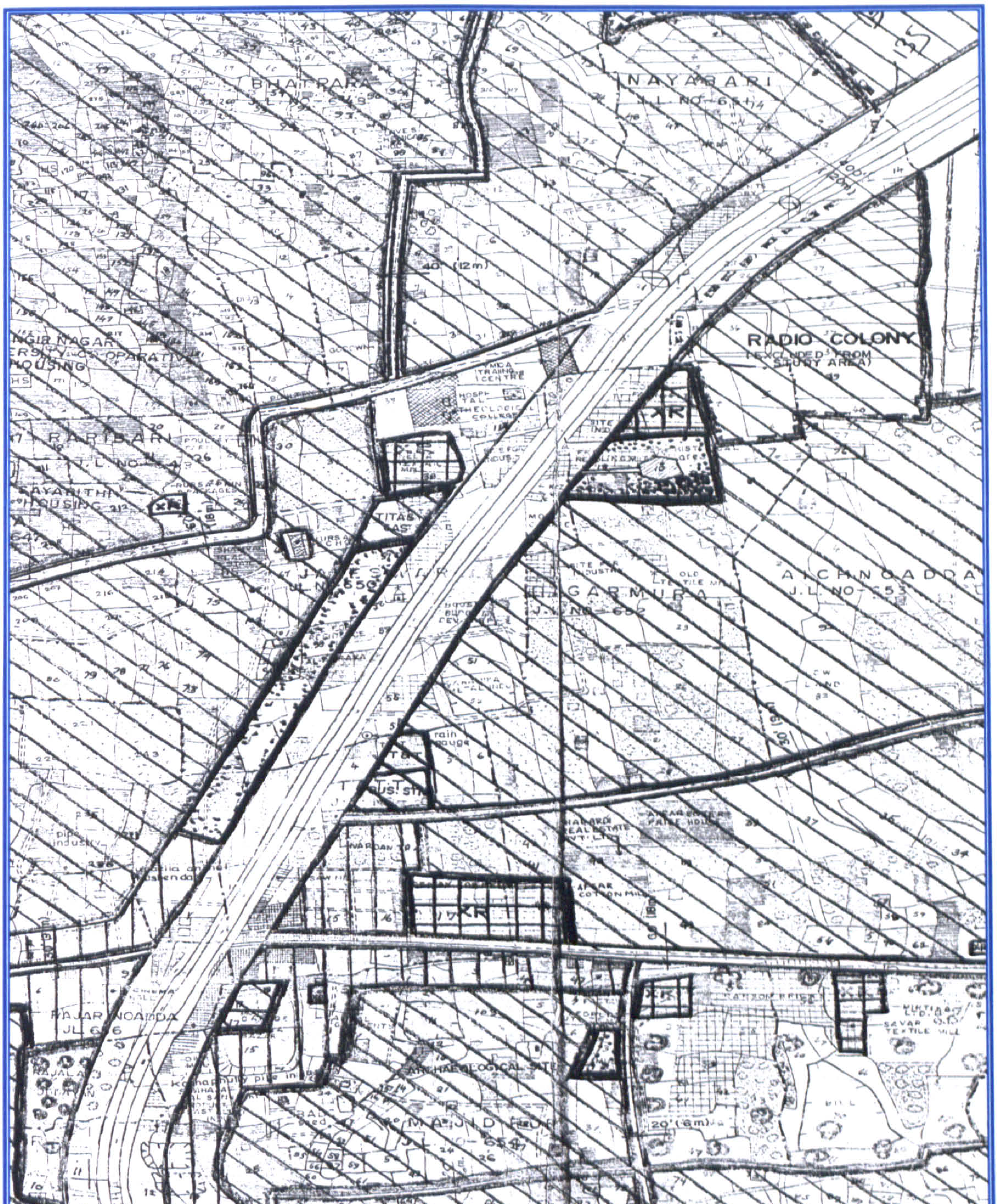


Figure 2-16: Rajuk sponsored a very detailed plan (1"=300 feet) at the plot level with plot numbers and their current and proposed land use of a small part of Savar Paurashava are shown above. This image is taken from Planning Sheet No 4, Land Use Master Plan (LU-01) of Savar Area (Phase 1) prepared by the local consulting firm Prakushali Sangshad Ltd. This plan contains invaluable information and all features for Savar Paurashava as a whole. The later dated, ADB backed Secondary Town Plan (Savar) does not mention anything about this plan. (Note: the original plan is in multi-colour but due to its huge size using a scanner I could not digitise it in colour, so I place it here in B/W as a sample image).

2.3.1. Sources of Remotely Sensed Images

To meet the research objectives, a series of decennial remotely sensed images are required. After the 1950s, rapid changes started and activities were initiated for the development of aerial and space images. The plan is to compare census data with population census data, and since 1951, at decadal intervals, the population census data are available in Bangladesh at mauza level, so remotely sensed images were required for equivalent dates. In the summary Table 2-10, a list of high resolution images is given for every decade, from the early 1950s to the present day. I have also listed Landsat and ADEOS images. These are used in the thesis to visualise the landscape.

Table 2-10: Summary information of RS Images and their comparisons of parameters

Resolution Class	Platform Name	Sensor	Month/Year	Mode/Band	Media	Resolution or Scale
High Resolution (used thoroughly)	Aerial Photography	----	02/**1953**	Black and White	Hard Copy	1:30,000
	CORONA Spy Photo-reconnaissance Satellites	KH-4	11/**1962**	Panoramic (Aft Looking)	Negative microfiches	6 metre
		KH-4B	04/**1972**			2 metre
	Aerial Photography	----	03/**1984**	B&W-Infrared	Hard Copy	1:30,000
		----	12/**1990**	Black and White		1:40,000
	IRS	1D (Optical Pan)	02/**2000**	0.50-0.75 microns, panchromatic	Raw Digital	5 meter
Medium Resolution Multi-spectral (used occasionally)	ADEOS-1	AVNIR	12/1996	Band 1-4*		16 metre
	Landsat 5	TM	10/1988	Band 2-4**		30 metre
			01/1997			
			04/1999			

Notes on Bands in microns:

*(1) Visible–Blue 0.40–0.50 (2) Visible–Green 0.52-0.60 (3) Visible–Red 0.62–0.72 (4) Photo/Reflected IR 0.82–0.92

** (2) Visible-Green 0.52-0.60 (3) Visible-Red 0.63-0.69 (4) Photo/Reflected IR 0.76-0.90

(a) Aerial Photos (1953, 1984 and 1990)

The acquisition of Aerial Photographs (AP) from the government agencies is always very difficult in Bangladesh, not least because it is theoretically against the law. Despite this, finally I succeeded to gather APs from a variety of undisclosed sources, as they understood my problem and were convinced that this research would ultimately benefit Bangladesh and would not harm the national interest. The records and maintenance of the old APs are very poor and a significant amount of old APs are already damaged seriously. These are highly valuable resources to keep track of our past history for future generations and in my view should be made available for bona fide researchers. It is ironic that APs are red taped while anybody can buy from commercial sources far better quality high-resolution images in digital format.

The first APs were acquired by the then Pakistan Government in 1953 in panchromatic form at 1:30,000 scale, primarily to implement its land reforms, natural resource management and agricultural developments. In 1984 the Bangladesh Government acquired images as infrared form in order to update mainly her topographic map sheets, and for military and development objectives. After devastating flood events in consecutive years in 1987 and 1988, a Flood Action Plan (FAP) was adopted by the government. In the last week of November 1990, the capital Dhaka was imaged from the air as a part of this programme to assess the river basin and to carry out a feasibility study to protect Dhaka by constructing an embankment. By 1993, the construction was completed but Savar was marginally outside.

To assess the quality of the CORONA images, there was no alternative but to use the APs. Besides, the APs gave a unique opportunity to develop a database parallel to the decennial population census. The APs were scanned at 800 dpi using a high quality flat bed scanner in one layer grey 'Tag Image File Format' (TIFF). All of the APs were later geo-corrected and calibrated using remote sensing techniques and highly accurate DGPS data collected during the fieldwork.

(b) CORONA Films (1962 and 1972)

This research fortunately coincided with the declassification of American military satellite photography for the first time. These data are rather different from the more familiar commercial satellite images and aerial photographs. President Clinton of the United States signed an Executive Order on 22 February 1995 directing the declassification of intelligence imagery collected between 1960 and 1972 by the first generation of US photo-reconnaissance satellites (Table 2-11); the programme was code-named CORONA, Argon and Lanyard. The intelligence community used the designators KH-1 (Keyhole–1), KH-2, KH-3, KH-4, KH-4A and KH-4B for the CORONA systems (*http:// edcwww.cr.usgs.gov /glis/hyper /guide/disp,* 2002). It took several years before the films were finally accessible to the research community.

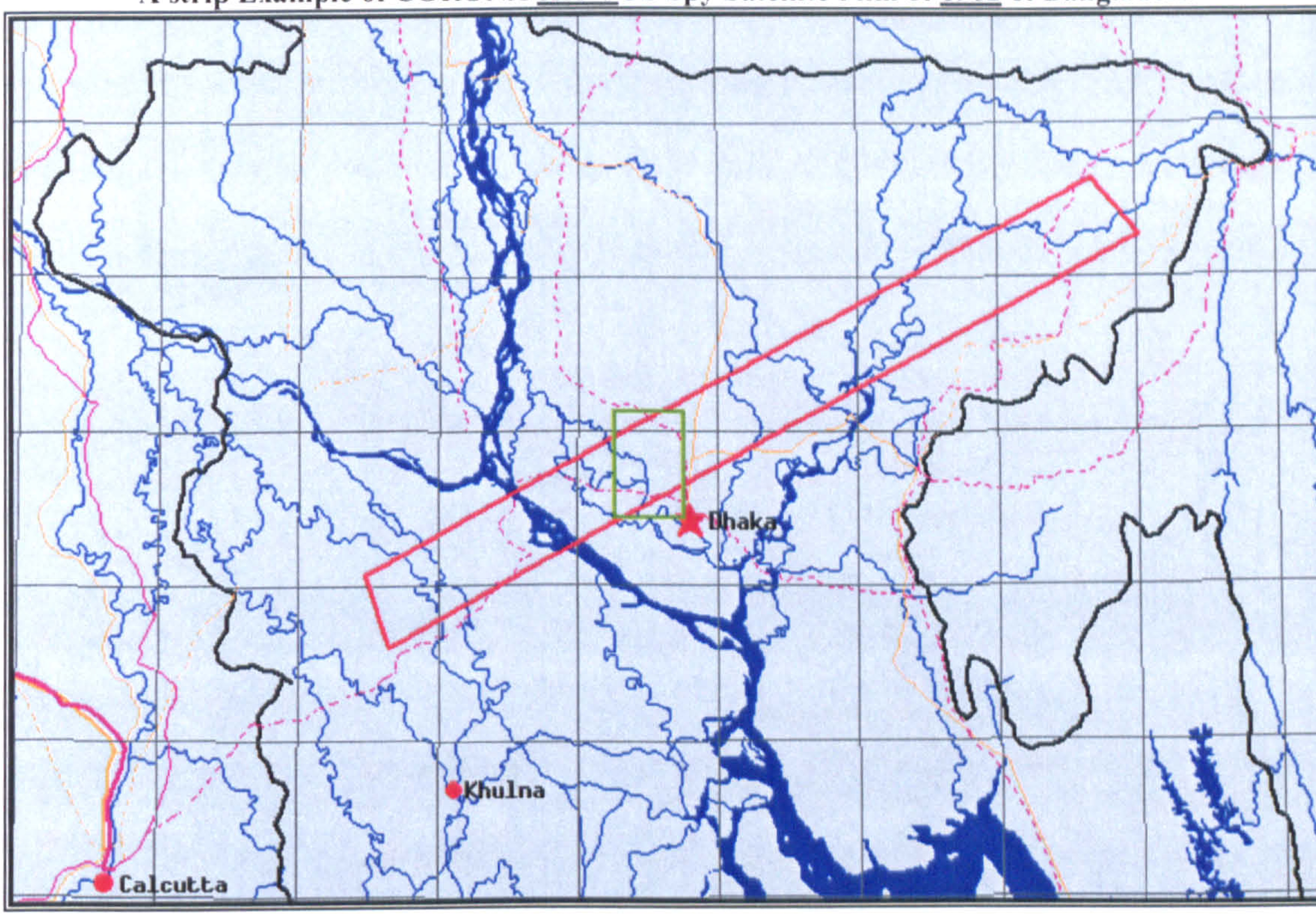
To achieve the goal of the study, high-resolution images were needed at decennial intervals and CORONA KH-4 for 1962 and KH-4B for 1972 were acquired as high quality of filmstrips. Out of a total of 148 known spy missions between 25 June 1959 and 25 May 1972, 14 negative microfiches (2.25"x29.8") from two missions were selected for this study of Savar upazila after a time-consuming, comprehensive and careful search of more than 860,000 image frames. These selected mission numbers were 9048 of 24 November 1962 acquired by CORONA KH-4 and 1116-1 of 22 April 1972 acquired by CORONA KH-4b. The 1962 film is of an area 15.3 km wide and 325 km long, while the 1972 strip is 13.8 km width and 188 km long. The films are of approximately 6 and 2 metre resolutions respectively. With the aim of comparing the CORONA 1962 and 1972 strips, please see the grids, which are unique in both cases given as examples in Figures 2-17 and 2-18.

The selected filmstrips were ordered using the internet (*http:// edc.usgs.gov /Webglis/glisbin /submitorder.pl*) from the Customer Services of USGS/EROS Data Centre (47914 252nd Street, Sioux Falls, SD 57198-0001, USA attn: GLIS Order). The study area was marked on the negatives and was digitised using a photogrammetric optical scanner at 7.5 micron resolution in TIFF file format by SDS (Survey and Development Services Ltd, *http://www .sds.co.uk*). The total size of the study area after the scanning was a more than gigabyte. This means that an entire microfilm contains about 18 gigabytes of digital data at 7.5 micron scan resolution.

The image preparation steps of the aft-looking panoramic CORONA photography were:

1. Surfing USGS web site;
2. Selecting CORONA negative films;
3. Purchasing films;
4. Identifying study sites;
5. Contacting a company with a suitable photogrammetric scanner;
6. Scanning at 7.5 microns;
7. Geo-referencing using DGPS based ground control points;
8. Digital image processing and integrating with GIS;
9. Adding field attributes or census data; and
10. Mapping and interpreting.

A strip Example of CORONA KH-4 US Spy Satellite Film of 1962 of Bangladesh



Film Reference: DS009048070DF265 9048 070D 265 1962/11/24 Y F 4

Metadata Details of the film

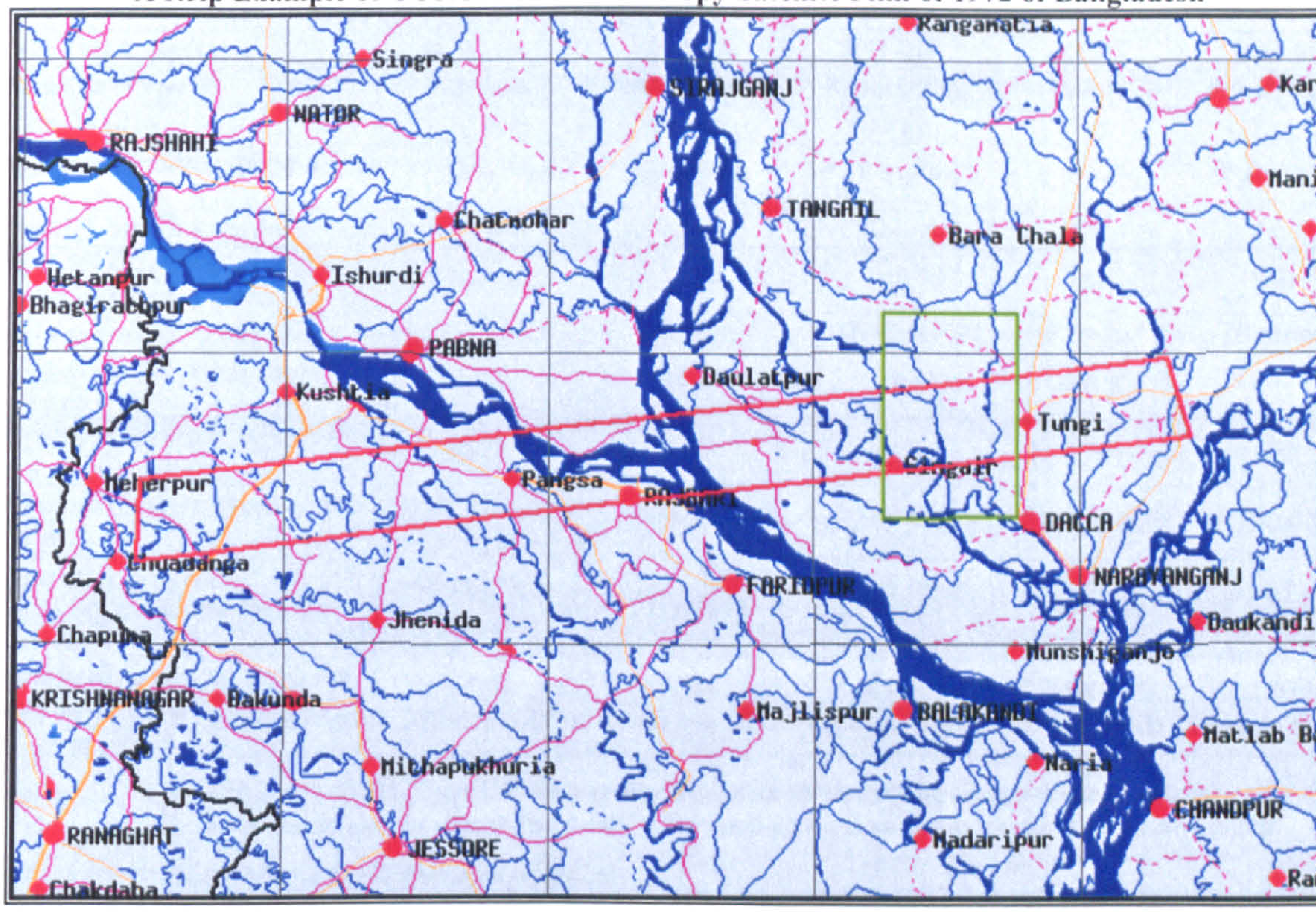
Entity Id: DS009048070DF265
Mission Number: 9048
Frame Number: 265
Acquisition Date: 1962/11/24
Browse Availability: YES
Camera Type: FORWARD
Camera/Resolution: STEREO MED
Revolution: 070D
Image Type: BLACK and WHITE
Film Type: 70mm PANORAMIC
Generation: 2
Polarity: NEGATIVE

Area Indicator:
Entity partially covers the search area
Northwest Latitude: N23 32
Northwest Longitude: E089 15
Northeast Latitude: N24 49
Northeast Longitude: E091 51
Southeast Latitude: N24 38
Southeast Longitude: E092 01
Southwest Latitude: N23 18
Southwest Longitude: E089 20
Browse Path:
9048/070D/F/DS009048070DF265.jpg

Data and image compiled from **http://edcwww.cr.usgs.gov/glis**, *2001*

Figure 2-17: The Map indicates the location of the CORONA 1962 KH4 given narrow and long red strip within the Bangladesh boundary (bold black lines) with the actual images and meta data details available for the each negative film. The strip was elongated from southwest to northeast. The small yellow box is the rectangular extent of the studied Savar upazila. The strip (red rectangular on the map) covers 15.3km x325 km (about 4972.5 km^2) of Bangladesh which means that the filmed area is about 18 times larger than the area of Savar with about 6-metre ground resolution and 100 lp/mm or 5000 dpi film resolution. For each camera type (forward and rear looking), at least three strips were partly required for the study area.

A strip Example of CORONA KH-4B US Spy Satellite Film of 1972 of Bangladesh



***Film Reference*:** DS1116-1039DF059 1116-1 039D 59 1972/04/22 Y F 5

Metadata Details of the film

Entity Id: DS1116-1039DF059
Mission Number: 1116-1
Frame Number: 59
Acquisition Date: 1972/04/22
Browse Availability: YES
Camera Type: FORWARD
Camera/Resolution: STEREO HIGH
Revolution: 039D
Image Type: BLACK and WHITE
Film Type: 70mm PANORAMIC
Generation: 2
Polarity: NEGATIVE

Area Indicator:
Entity partially covers the search area
Northwest Latitude: N23 47
Northwest Longitude: E088 44
Northeast Latitude: N23 59
Northeast Longitude: E090 40
Southeast Latitude: N23 51
Southeast Longitude: E090 43
Southwest Latitude: N23 38
Southwest Longitude: E088 43
Browse Path:
1116-1/039D/F/DS1116-1039DF059.jpg

Data and image compiled from **http://edcwww.cr.usgs.gov/glis,** *2001*

Figure 2-18: The example shows the location of the CORONA 1972 KH4B given narrow and long red strip on Bangladesh territory (bold black boundary) with the actual images and metadata details available for each film. The strip was elongated from west to east. The small yellow box is the rectangular extent of Savar upazila. Each negative filmstrip (red rectangular on the map) covers 13.8km x188 km (about 2594.4 km^2) of Bangladesh which means that the filmed area is about 9 times larger than the area of Savar with about a 2-metre ground resolution and 160 lp/mm or 8000 dpi film resolution. At least four strips were partly required for the study area in order to carry out this research.

Table 2-11: Various types of the CORONA sensors and their system configurations with resolutions

CORONA System	KH-1-4*	KH-4A	KH-4B	KH-5	KH-6
Camera Type	Panoramic	Panoramic	Panoramic	Frame	Panoramic
Film Width	70 mm	70 mm	70 mm	5 in	5 in
Approx. Frame Format (in. x in.)	2.18 x 29.8	2.18x29.8	2.18 x 29.8	4.5 x 4.5	4.5 x 25
Focal Length (inches)	24	24	24	3	66
Best Resolution of Film (approximate) (lines/mm)	50-100	120	160	30	160
Enlargement Capability	<10 times	16 times	16 times	8 times	16 times
Best Ground Resolution (approx.)	25 ft	9 ft	6 ft	460 ft	6 ft
Nominal System Altitude (nautical miles)	90-250	100	81	174	93
Nominal Photo Scale on Film	1:275,000 to 1:760,000	305,000	1:247,500	1:4,250,000	1:100,000
Nominal Ground Coverage/Image Frame (miles)	9.5X130 to 26X360	10.6X144	8.6X117	300X300	7.5 X 40
Nominal Ground Sample Distance of GLIS** Browse Image	530 (feet/pixel)	530 (feet/pixel)	430 (feet/pixel)	4000 (feet/pixel)	180 (feet/pixel)

Notes: * The KH-1, KH-2, KH-3, and KH-4 are grouped together for describing camera-related features. The KH-4 designator was sometimes used by the Intelligence Community to refer to the entire group.

** GLIS - Global Land Information System

*Data compiled from **http://edcwww.cr.usgs.gov/glis/hyper/guide/disp**, 1999*

Instructions Given for Film Scanning

A total of 16 CORONA black and white negative films were sent for digital scanning at 7.5 micron accuracy. The proposed scanning areas were marked by non-adhesive red tape and in yellow 'chinagraph' colours on the films and on film covers respectively with instructions to scan only within the marked area. The original printed numbers of negatives are located either on the side border (for 22-04-1972 films) or on the top border (for 24-11-1962 films). More particularly the digits beginning with D are negative numbers. The original spatial resolution of 1972 negatives (D039... series) are very high (approximately 3 microns or 8000 dpi or 160 lines/mm) and of 1962 (D70... series) are medium to high spatial resolution (approx. 5 microns or ~5000 dpi or 100 lines/mm). The following parameters were used for scanning the films (Table 2-12):

Table 2-12: Monochrome film scanning Parameters at 7.5 microns as mentioned in the RH file used by SDI Scotland for each CORONA Microfiches, in March 2000

Num_Tags	Int	1	26	Sizpix_X	Int	1	30508
Roi_Base	Str	1	Do39063	Sizpix_Y	Int	1	9400
Device	Int	1	0	Resmp	Dbl	1	7.500000
Offul_X	Int	1	0	Depth_W	Bool	1	1
Offul_Y	Int	1	0	Sat_W	Dbl	1	2.612000
				Contrast_	Wdbl	1	215.468000
Ul_X	Int	1	370896	Depth_R	Bool	1	0
Ul_Y	Int	1	114214	Depth_G	Bool	1	0
Ur_X	Int	1	142086	Depth_B	Bool	1	0
Ur_Y	Int	1	114214	Overlap	Int	1	7
Ll_X	Int	1	370896	Tile_Size_X	Int	1	932
Ll_Y	Int	1	184714	Tile_Size_Y	Int	1	947
Lr_X	Int	1	142086	Num_Tiles_X	Int	1	33
Lr_Y	Int	1	184714	Num_Tiles_Y	Int	1	10

Source: SDI- Scotland, EH51 0AA (Fax 01506 517777), 2000

(c) IRS-1D (2000)

The IRS (Indian Remote Sensing) 1D, 2nd generation satellite after IRS 1C (Dec, 1995), was launched from Sriharikota, India on 29th Sept 1997. This polar orbitiry, sun synchronous satellite contains a payload of panchromatic camera and multispectral sensor. The panchromatic scanner provides data with a spatial resolution of 5.2-5.8 metre (at nadir). It operates in the 0.50-0.75 micro metre spectral band. It orbits at a mean altitude of 780 km with an equatorial crossing time of 10:30am-10:47am in descending node. The camera can be steered up to ± 26° (steerable up to ± 398 km across the tract from Nadir), which in turn increases the revisit capability to 3 days for most part of the cycle and 7 days in some cases. The general swath for panchromatic imagery is between 63 and 70 km (NRSA, 1997). In my research I have used February 2000 IRS-1D images for Savar upazila.

Apart from high resolution IRS-1D commercial satellite images, I also used medium resolution ADEOS and Landsat 5 images. Table 2-13 summarises these data. The spectral bands shown in bold have been used in the study.

Table 2-13: Comparison of different commercial satellites parameters used in this study

Parameters	Landsat 5 (National Aeronautic and Space Administration, USA)	ADEOS (Advanced Earth Observation Satellite/ Midori is called in Japan)	IRS-1D (National Remote Sensing Agency of India)
Imaging Sensors	TM (Thematic Mapper)	AVNIR (Advanced Visible and Near Infrared Radiometer)	PAN, LISS-III and WiFS
Spectral Region (Bands) In Microns (μm)	0.45-0.52 (1) Visible - Blue **0.52-0.60 (2) Visible - Green** **0.63-0.69 (3) Visible - Red** **0.76-0.90 (4) Photo/Reflected IR** 1.55-1.75 (5) Reflected/Near IR 2.08-2.35 (7) Reflected/Mid IR 10.4-12.5 (6) Thermal/Far IR	**0.40 – 0.50 (1) Visible – Blue** **0.52 - 0.60 (2) Visible – Green** **0.62 – 0.72 (3) Visible – Red** **0.82 – 0.92 (4) Photo/Reflected IR** 0.52 – 0.72 (5) Panchromatic	052 - 0.59 (2) Visible - Green 0.62 - 0.68 (3) Visible - Red 0.77 -0.86 (4) Photo/Reflected IR 1.55 – 1.70 (5) Reflected/Near IR **0.50 – 0.75 (1) Panchromatic**
Orbital Charact. (Inclination)	Near -Polar, Sun-synchronous (99.2°)	Sun-synchronous, Subrecurrent Orbit (98.62°)	Near -Polar, Sun-synchronous (98.53°)
Repeat Cycle	16 days	41 days	3 days (but 25 days for LISS-III)
Time of Data Acquisition	9:45 ±15 minutes A.M. (Local Sun Time)	10:30±15 minutes A.M. (Local Sun Time)	10:30 to 10:47 A.M. (Local Sun Time)
Data Availability	Since March 1984	17-Aug-1996 to 30-June-1997	Since 29-Sep-1997
Agency / Country	NASA / NOAA of USA	NASDA (National Space Agency of Japan)	National Remote Sensing Agency (NRSA) of India
Altitude	705 km	802.9 km	780 km
Period	99 minutes	101 minutes	-----
Incident/Look Angle	14°92'	±40°	±26°
Resolution at nadir	**30 metres**	**16 metres - Multispectral (MS)** 8 metres - Panchromatic (P) Band	21-23 metres - Multispectral (MS) **5.2-5.8 metres - Panchromatic (P)**
Ground Image Size	185 km x 172 km	60 km x 60 km	63-70 km (Pan), about 130 km for Multispectral
Digital Format of Image	5760 lines x 6928 pixels	7252 Lines x 4997 Pixels (spectral)	13591 Lines x 14166 Pixels Pan-mode
Data Rate	84.9 Mbit/S	66 Mbit/S	42.4515 Mbit/S

Sources: compiled from various sources, 2002.

2.3.2. Sources of Primary Data

(a) DGPS data (2001)

Differential Global Positioning System (DGPS) data can be seen as the backbone of the all map and image data because it underpins the geometric accuracy of the data, particularly of maps at the 1:3,960 scale. The DGPS survey was essential for several reasons, for example:

(1) For geocorrection of the images and maps (e.g. raw IRS-1D satellite image);

(2) To verify the quality of existing data (e.g. existing road maps); and

(3) To map the landmark or major land features (e.g. pukurs, schools) on the image.

With the help of local designated experts I used a Trimble GPS Pathfinder Pro XR with submetre (*50cm+1ppm on a second-by-second basis for horizontal*) RMS accuracy by using MKS radio-beacon real-time differential capabilities. The output through 'Asset Surveyors' software was robust and powerful for mapping, remote sensing ground truthing and GIS applications. Figure 2-19 is an example of official LGED road maps compared with a road map I prepared by DGPS methods in March 2001. All of the DGPS-based roads were accurately matched with the imagery but the LGED printed maps proved to be very crude and misleading and therefore unsuitable for this study.

(b) Fieldwork ((November 2000 to March 2001)

My four months of fieldwork involved observation, interviewing, questionnaire survey, collecting unpublished documents, photography and video. Prior to this, I developed the necessary paper work and printings (e.g. A00 size CORONA Image Printing at 1:17,000 scale). The elements of fieldwork were as follows:

(1) Departure from UK and arrival in Savar upazila on 1st of November, 2000;
(2) Visiting Jahangirnagar University (JU) and selecting & training of Field Assistants;
(3) Buying and Digitising of Mauza Maps and Attribute Data Entry;
(4) Observing selected villages and ice-breaking with local peoples;
(5) Identifying 'Key informants' and interviewing them;
(6) Surveying selected mauzas & identifying land-use and land values change factors;
(7) Surveying Villages with DGPS and Keeping tracts on Printed Maps;
(8) Surveying roads, infrastructures and land features with DGPS – RS Images;
(9) Buying Aerial Photos and Tracing, digitising and Scanning;
(10) Meeting 'Key Informants' with maps and images/getting necessary feedback;
(11) Participating in Census Survey 2001 and collecting Raw population data;
(12) Ground Checking of CORONA and other RS Images and interpretations;
(13) Collecting published and unpublished materials/documents on Savar;

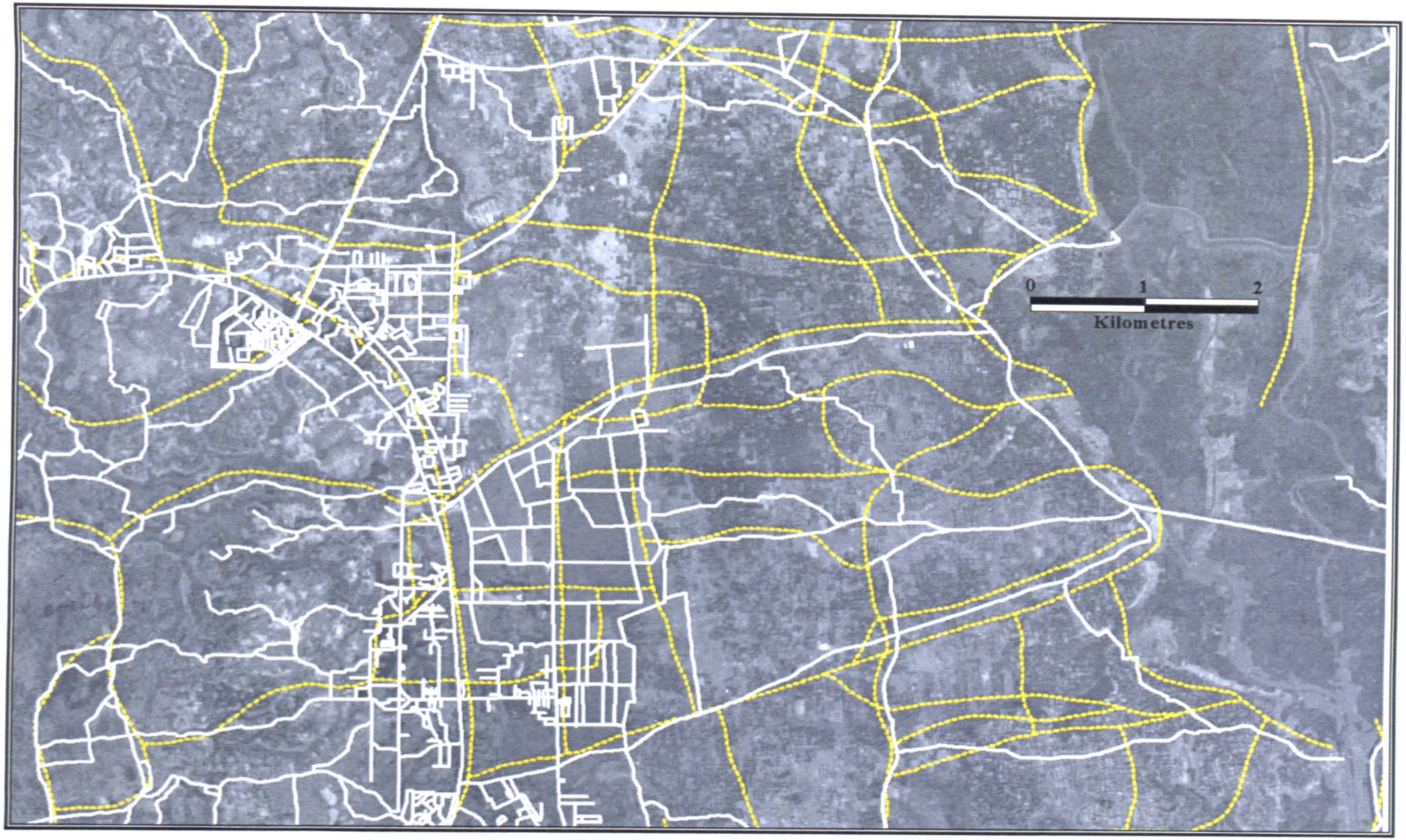


Figure 2-19: The dotted yellow lines are from the LGED road map based on poor quality traditional sources and the embedded white roads are based on DGPS survey which is exactly matching with road visible on the high resolution RS images (e.g.IRS-1D is shown as background). The illustrated area is part of Ashulia and Pathalia Unions.

(14) Interviews with Government, planning and Local Authorities and villagers;
(15) Videoing and photographing fields, people and key interviews;
(16) Verifying Both Population Census Data and maps;
(17) Field data tabulation and entry in computer and primary output;
(18) Giving a seminar at JU on PhD work & getting Feed Back from staff;
(19) Reviewing field data and consistency checking and correcting;
(20) Preparing a Brief Progress Report and emailing it to Supervisors;
(21) Receiving Supervisors' response & arriving back in Durham on 26th of March 2001.

It is to be mentioned here that all photos used in the thesis are taken by me during the field work and have been cited throughout the research. These photos provided invaluable evidence for interpretation and explanatory purposes.

2.3.3. Sources of Secondary Data

(a) Population Censuses (1951-2001)

Bangladesh has inherited a long tradition of conducting the population census on a decennial basis since the colonial days of 1872 of the colonial past. As my research focuses on is the period between 1951-2001, I have used the census reports of the Pakistan Period (1951 and 1961) and Bangladesh Period since the 1974 census. All of the census surveys were conducted during the winter season of Bangladesh (GoP 1956 and 1964; BBS 1979, 1985 and 1994). For example, the last two, thirteenth and fourteenth, population censuses were conducted during March 12-15, 1991 and January 23-27, 2001. The main objective of the census was to collect information about the basic characteristics related to housing and population for developing a comprehensive data base for all development programmes as well as economic management. The population census is the only source of detailed and comprehensive data in Bangladesh providing the size, spatial distribution and basic characteristics of the population from mauza level to union to district to national level. Population census reports were the only source of population data for the current research work. The following parameters were mainly published at the mauza level: the total number of households; total number of population; number of males; number of females; and literacy rate.

2.3.4. Sources of Secondary Maps

The details of the maps are a very important part of this research. All GIS data/ coverage/ layouts and RS images have been digitised, clipped and overlayed on the basis of this information. Moreover, GPS survey during the fieldwork was conducted with the help of the map information. Some historical information was also collected and compiled from maps. Projection information (Latitude and Longitude or Geo-references) was gathered as well, particularly the location of mauzas, unions, paurashava and roads. Some maps are the true records of the past history but in some cases, due to the lack of survey skills and inefficiency of the personnel involved with field survey, compilation and cartographic work, some errors may have been introduced in comparison with the real ground status. In Bangladesh a lot of organisations are involved in developing maps for their own purposes. In Table 2-14, the common sources of maps in Bangladesh are listed but a brief description and background of some maps is given in the following sections.

Table 2-14: Summary information of the maps commonly available study. Underneath the 'known as' column, the map's name is given as popularly known in Bangladesh.

No	Known As:	Detail Title of the Map	Scale	Organisation
1	**Mauza Map (1967)**	Savar Mauza under Savar Thana (RS# 686, JL#167, Sheets: 1, 2 and 3)	1: 3,960	Settlement Office and Superintendent of Survey
2	**Land use Guide Plan (1990)**	Landuse / Master Plan of Savar Area (Phase 1) Plan LU-01, Landuse Guide Plan (Number of sheets 10)	1: 3,960	RAJUK (Rajdhani Unnayan Kartipakkha)
3	**Topo-sheet (1973)**	Topographic Map - 2nd Edition (Mainly Index no. 79 i/5 and 79 i/1) - Restricted Version	1:50,000	Survey of Bangladesh
4	**Thana Map (1924)**	Police Station Sabhar, Revenue Thana Sabhar, Part –1	1:63,360	Drawing Office Bengal
5	**Upazila Base Map (1994)**	Base Map, Savar Thana, Zila Dhaka	1:50,000	Local Government Engineering Department (LGED) and UNDP
6	**Soil Map (1992)**	Soil and Land type Map, Savar Thana	1:50,000	Soil Resources Development Institute (SRDI), Dhaka
7	**Road Map (1992)**	Road Map – 1 (Version 2), Savar Thana	1:50,000	Savar Upazila LGED Office
8	**Land use Map (1994)**	Land Use/Water Use Map, Savar Thana	1:50,000	Savar Upazila LGED Office
9	**Homestead (1993)**	Homestead and Water bodies Map, Savar Thana	1:50,000	Savar Upazila LGED Office
10	**Drainage Map (1994)**	Drainage and Embankment Map –1, Savar Thana	1:50,000	Savar Upazila LGED Office
11	**Irrigation Map (1994)**	Irrigation Map –1, Savar Upazila	1:50,000	Savar Upazila LGED Office
12	**RAJUK Composite Plan (1997)**	Composite Policies Map (1995-2015): Dhaka Metropolitan Development Plan	1:50,000	RAJUK/UNDP/UNCHS
13	**RAJUK Transport Plan (1997)**	Integrated Transport Network (1995-2015): Dhaka Metropolitan Development Plan	1:50,000	RAJUK/UNDP/UNCHS
14	**RAJUK Urban Plan (1997)**	Dhaka Urban Area Plan (1995-2005): Dhaka Metropolitan Development Plan	1:30,000	RAJUK/UNDP/UNCHS
15	**RAJUK Drainage Plan (1997)**	Drainage and Flood Protection System of Urban Area: Dhaka Metropolitan Development Plan	1:30,000	RAJUK/UNDP/UNCHS
16	**District Map (1958)**	District Dacca (Administrative map of Greater Dhaka)	1: 253,440	Bengal Drawing Office
17	**Paurashava Map (1995)**	Savar Paurashava (Savar Municipality)	not shown	Savar Upazila LGED Office
18	**BBS Atlas (1985)**	*Mauzas* and *Mahallas* of Dhaka District, Small Area Atlas of Bangladesh	1:200,000	Bangladesh Bureau of Statistics under Ministry of Planning

(a) Medium Scale Maps (e.g. 1:50,000): Upazila Level

Thana Map (1924): This is the one of the oldest maps of Savar upazila that is still widely used in Bangladesh in Government Offices as well as in academia. This map is the base map of the all currently used maps at upazila level (1:50,000 Scale). The map is known as ***'Police Station Sabhar*[2]*, Revenue Thana Sabhar, Part I, District Dhaka'***. Sabhar thana then consisted of three police stations. These were, Part I: P.S. Sabhar, Part II: P.S. Kaliakoir, Part III: P.S. Dhamrai. Now all of these police stations are in separate, independent upazila. The Sabhar P.S. map was surveyed in 1913-14 at a scale of 1"= 1 mile (i.e. 1:63,360). It was published under the authority of the then Government in 1924 by the Drawing Office, Bengal. The map was reprinted in 1983 with a minor modification under the notifications of no. PIJ-5/78 MHA (Police-1) 835 dated 2-12-1978. Under this notification some north-eastern mauzas/villages of Savar upazila (Kashimpur Union) were transferred to the then Jaydevpur P.S. of District Dhaka (Now known as Gazipur District). In the 1924 map, a mauza was referred as a village. The major features in the map were district boundaries, revenue upazila, police stations, village boundaries, unmetalled roads stone, village cart-tracks, foot paths, tanks, mosques/temples/churches, police head quarters, post offices, telegraph offices, dak *bungalows*, rest houses, inspection *bungalows*. Moreover, the names of the villages, remarkable tree plantations, *shaal* forests, grass lands, rivers showing the direction of flow, khals, natural water bodies, the name of the mauzas with their reference numbers, and steamer stations. It was also mentioned that Lalbag (one the oldest urban areas) was 5 miles away from the Amin Bazaar Union. There were no pucca (metalled) roads in Savar upazila at that time and

[2] *The spelling of Savar was written in this map like Sabhar while in the Rennell's map of 1778, Savar was written as Saabar.*

certainly no national highways. The projection of this map still uses lines of latitude and longitude.

Upazila Base Map (1994): The title of this map was the '***Base Map, Thana Savar, Zila Dhaka***'. The Definition of a **Thana**, in short, *is a police station which has subsequently developed into a revenue and/or development circle.* The boundaries of *thanas* are similar to the current *upazila* boundaries at first initiated by the Jatiya Party Government in 1982. Later during the rule of the BNP, 1991-1996, this administrative model was dropped. The later Awami League Government (1996-2001) again *restablished* the upazila system and a Bill was passed by the National Parliament in 1999. The thana has been renamed the upazila. It (thana/upazila) is the third order local government unit in Bangladesh below the Division and District and may also to be considered as an electoral unit of the upazila parishad under the upazila system. It consists of a number of unions and perhaps a paurashava.

However, as claimed, this Savar upazila map, was compiled from SPOT images of 1989, aerial photographs of 1983-84, topographic maps, Thana maps, B.B.S. (Bangladesh Bureau of Statistics) and field checking. The projection of the map was Lambert's Conformal Conic (details of the projection are placed in a separate section), The map was prepared by the Local Government Engineering Department (LGED) under the UNDP/ILO Project (BGD/89/041) in 1994. The database of the map is based on J.L. No and Geo-code Number and corresponding name of the mauzas. J.L. refers to the Jurisdiction List number numerically identifying mauzas for cadastral, revenue and administrative purposes within a upazila. On the other hand, the geo-code number refers to a geographic area code number for recoding statistical data with reference to spatial areas.

There is a wide range of information available on the map. These are ***boundaries*** (International, district, upazila, union, mauza, urban area/paurashava); ***headquarters*** (district, upazila, union, police station); ***natural features*** (river with char areas, khal, water bodies: beel/haor/baor, tank/pond); ***physical infrastructures*** (national/regional highway, feeder roads: type A, feeder roads: type B pucca, Feeder type B katcha, paurashava/local/rural pucca road: R-1/R-2/R3, paurashava/local/rural katcha roads: R-1/R-2/R3, telecommunications, transmission lines, bus stops with passenger shed, bridges/culverts); ***agricultural infrastructures*** (embankments, road cum embankments, deep/shallow tubes well/LLP); ***socio-economic infrastructures*** (growth centres, hat/bazaar/trading centres, hospital/upazila health complexes, dispensary/clinics, family planning centres, food godown, banks, mills/factories, post offices/telegraph offices, historical places /tourist spots, universities, colleges, high schools, primary schools, madrashas, mosque/church/temples, graveyard/cemetery/burning *ghat*) and ***settlement areas***. The scale of the map is 1:50,000 and is given an index to adjoining areas.

According to this map, Savar upazila was divided into 12 Unions. These are Savar (code 78), Simulia (code 83), Biralia (code 33), Bhakurta (27), Kaundia (code 50), Banagram (code 22), Amin Bazaar (code 05), Tetul Jhora (code 89), Dhamsona (39), Yearpur (code 94), Ashulia (code 11), and Pathalia (code 72). Currently the union is the smallest electoral unit of Bangladesh. The union is the fourth order local government unit of Bangladesh and is immediately below the upazila, which is comprised of mauzas and/or villages. There are 276 mauzas in Savar upazila though only 246 mauzas are actually shown on this map due to serious negligence of the concerned people involved with this upazila-base-map-project.

Road Map (1999): This map was last updated in 1999. The title of the map is ***'Road Map - 1 (Revision 2), Savar Thana, Zila Dhaka'***. The map is published by the Local Government Engineering Department (LGED) under the Government of the People's Republic of Bangladesh. The scale of the map is 1:50,000. The major focus of the map is roads and their associated infrastructures, for example, national highway (Dhaka-Aricha Highway), Feeder Road (type-A), Feeder Road (type-B), Feeder Road (type-B) *Pucca* (metalled), Feeder Road (type-B) *Katcha* (unmetalled), Paurashava Local/Rural Pucca Road (R-1, R-2, R-3), bridge /culvert, Road cum Embankment, Sluice / Regulator, Growth Centre, Hat / Bazaar, Mill / Factory. It also contains information about the administrative boundaries and names of district, upazila, union, mauza, paurashava and the location of upazila, union and police headquarters. There is some information about a few natural features such as Khal, Beel /Haor /Baor, Pond/Tank.

Topo-sheet (1973): Though the title is not shown in the map due to its mainly military usage, it is widely known to academics and surveyors as the ***Topo-Sheet*** or ***Topographic Map***. Even 100 year old topo-sheets are still restricted though the maps are readily available in neighbouring countries and in UK libraries. The map was rectangular in shape and contains an index to adjacent sheets. It is not, therefore, based on any administrative boundary. However, the index numbers for Savar upazila are within western half part of $79^{I}/_{5}$ sheet (i.e. in this sheet, about 85 percent of Savar upazila is located exactly between 90°15'00.00" and 90°21'36.70" East), the eastern half part is situated in $79^{I}/_{1}$ sheet (i.e. in this sheet, almost rest of Savar upazila area is located exactly between 90°11'08.45" and 90°15'00.00" East), and two very small parts of Savar are located in the south-eastern corner of sheet number $79^{I}/_{4}$ and top most part of the sheet $79^{I}/_{6}$.

This can be shown as follow (Figure 2-20), the relatively dark areas are indicating the location of Savar upazila.

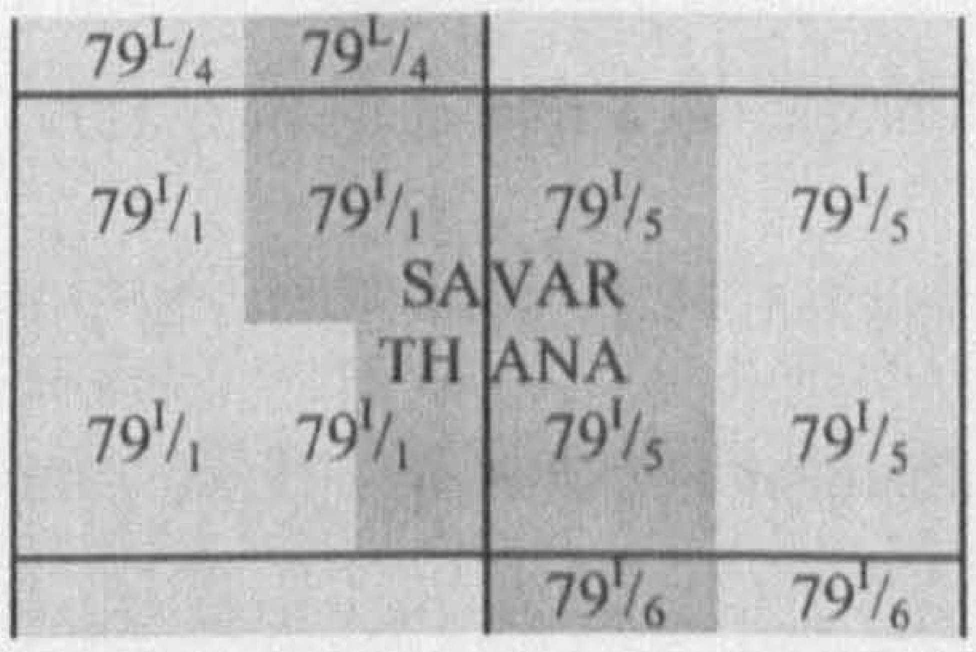


Figure 2-20: Index to Sheets of Savar upazila with Reference Number (Darker Areas)

For locating the exact position of the infrastructures and verifying with GPS mechanism, there is no alternative to using the topographic map sheets. That is why the topo-sheets are widely used for military purposes. Due to its high degree of positional accuracy, these maps can be use to accurately locate features identified on satellite images and aerial photography. However, the topo-sheets were compiled from the 4- inches to a mile upazila map, a 16 inches to a mile cadastral map. The grid references are also given on the sheet in hundreds of yards. The main surveys were executed by the then Land Records Department of Bengal in 1910 and generally corrected from air photographs on 16 inches to a mile scale taken by Messrs Air Survey Company Ltd. London during 1952-53 and revised on the ground during 1973. The Mean Grid North in the sheet is 0°16' East of True North and Magnetic Declination was about 0°50' West in 1967. The map was published under the direction of the Surveyor General of Bangladesh in 1979. The scale of the map is 1:50,000 or 1 inch to 0.789 mile. The available features in the sheets are: Roads (surface width about 20 feet and 12 feet); Cart-track , pack-track and foot path, river banks (shelving, steep 10-20 feet, over 20 feet; tidal river, swamp and reeds; wells (lined/unlined) spring, tanks (perennial/dry), villages (including deserted), huts (permanent and temporary); mosques, *idgah*, tombs, churches, temples, mot; cultivated areas, grass, cane , bamboo, plantain; trees (prominent) palms, scrub; boundaries (district, subdivision etc.) and names (important place/ villages/ built up area/ locality/ tribal) etc.

RAJUK Composite Plan (1997): This area of the map is the full RAJUK Jurisdiction area of Dhaka including Savar upazila. The title of the map is ***Composite Policies Plan, DMDP: Structure Plan 1995-2015, Dhaka Metropolitan Development Planning (DMDP) Area***. RAJUK prepared the map and the master plan under the financial support of UNDP and UNCHS. The scale of the map is 1: 50,000. The features of the map are RAJUK boundaries, existing primary roads, existing secondary roads, existing tertiary roads, existing main rail lines, existing main bridges, main rivers and khals, existing flood walls, proposed bridges, the proposed eastern by pass, proposed primary roads, proposed secondary roads, proposed flood embankments, proposed flood walls, proposed flood retention ponds, proposed mass rail transport, the established urban area up to 1989 (consolidation), agricultural high value areas, agricultural areas, urban fringe areas (acceleration), new urban land developments (enablement), proposed recreation/public facility areas, main flood flow areas, watershed protection areas, special areas, and cantonment security zones. However, all of the features may not be available in the Savar part of the map.

(b) Large Scale Maps (e.g. 1:3,960): Mauza Level

Mauza maps are the largest or micro scale maps available in Bangladesh. These maps are highly compatible with the high resolution imagery. The last analysis chapter has given special emphasis to the mauza. But how the maps originated is very important to know and it will have the greatest importance to my study. We will be able to understand the context and interesting history of this widely available types of map.

<u>A Brief History of Mauza Maps</u>

According to GoEP (1962), Hussain (1995) and Debnath (2000), in 1701 during the time of King Akbar of Indian subcontinent (*Bharat-barsho*), the land survey, record, mapping and modern revenue collection system were introduced for the first time under the Mughal Empire. This was widely known as Todar Mall's settlements. The system lasted about two centuries. At that time, revenues were collected directly from the farmers or tillers of the soil. The decline of the Mughal Empire began to change Bengal's history after 1757 and within years, in 1765, the East India Company established the foundation of British revenue jurisdiction in the provinces of Bengal, Bihar and Orissa. As an immediate impact of the power transition, one-third of the population of Bengal died due to a devastating famine in 1769-70 (Bangla Calendar: 1176, still locally remember as *Chhiattor-er Manantor*), so the East India Company was unable to collect the expected revenue directly from the insolvent and skeletal farmers. They decided instead to appoint local intermediaries (*jamindars*) in order to force extra revenues indirectly, and also they wanted to stay away from direct conflict with the farmers.

On 23rd March 1793, the terms of the Decennial Settlement of 1789-1790 were made permanent by Lord Cornwallis, with the result that the permanently settled states, including Bengal, become liable for no further increase in Land Revenue and, in order to increase revenues dramatically, the *jamindars* were declared to be the proprietors of the soil for ever as intermediaries. The *jamindars* were liable to pay the agreed revenues to the

East India Company and no excuse such as drought, flood or famine was to be accepted for non-payment. This was known as the notorious 'sun-set law'.

Meanwhile, based on the century-old Todar Mall's comprehensive survey of land, it became increasingly difficult efficiently to administer the Permanently Settled areas, and the help of the Revenue Surveyor was called in to settle, once and for all, the limits of estates and to make such maps of them as would eliminate the possibility of future disputes. The government generally fixed the rent for a limited term of years or else farmed out the estates to suitable persons who settled tenants and collect the rents. This usually necessitated what is known as a *'riyatwari'* or field-by-field survey. During the period 1845-1877, the *thakbastor* or demarcation survey was conducted which was based on eye-sketches with rough magnetic bearings. The general rule was to place *Thak* marks at measures intervals of 200 to 300 feet round a boundary and to place *dhuis* (large mud pillars of 5 feet high) at principal bends in the village boundaries and at all village triangulations. These were shown on Thak maps and were used later as rough guidance for the Revenue Surveyors between 1846 and 1878. The maps were known as Khasra Maps. The objectives of the Khasra Operation were to (GoB, 1917):

- Make accurate maps of the village boundaries and sometime the estate boundaries;
- Survey the topographical details that occurred with and around villages;
- Compile certain statistical data required for the general administration purposes;
- Make maps of each village (e.g. 4"=1 mile) and 1"=1 mile for Parganas.

The detailed boundaries were mapped either by ordinary plane table survey or by offsets to the traverse or by direct transfer of Thak boundaries. Based on the above survey, the modern Cadastral Survey (CS) maps (16"=1 mile) up to plot level were developed by finally replacing Todar Mall's system in the late 19th century, commencing from 1888, using traverse survey. The cadastral work showed the proper position, the actual limits of all cultivators' fields or such sub-divisions or amalgamations of these fields as may be required by the rules framed for the Settlement work which was to follow (Hussain 1995) and so on. These highly accurate large-scale maps, later popularly known as 'mauza maps', made in the field were reproduced mechanically for revenue collection purposes by the then district settlement department and, finally, since then these are the <u>'unique and invaluable land record contribution'</u> of the British Empire during the 200 years or so colonial period.

<u>The East Bengal State Acquisition and Tenancy Act, 1951:</u> After the independence of Pakistan from the British Rule in 1947, the East Bengal State Acquisition and Tenancy Act was passed by the East Pakistan Legislative Assembly on 19 May 1951 to abolish the brutal *Jamindar Protha* (landlord system). Among others, the main provisions of this historic law were (GoEP, 1962):

- All rent-receiving interests from those of Jamindars, Talukdars and other intermediaries to those just above the actual tillers of the soil were abolished;
- Further subletting of the lands by the ground tenants was prohibited;
- A ceiling on holding of land was imposed (maximum 33 acres i.e. 100 bighas), beyond which excess lands would be vested in the Government.

Immediately after the independence of Bangladesh, under consideration of the poor economic and social conditions of the villagers in 1972, *raiyats* (tenants) having 25 *bighas* (8 acres) of land or less per family were each exempted from paying any rent or tax (GoB 1972).

Since 1951, all mauza maps have been maintained by the Land Records and Surveying Department and mainly used for efficient revenue collection. In the Pakistan period, after implementing the State Acquisition Act, 1951, all mauzas were updated and resurveyed in the 1960s. These were later known as the Revenue Survey mauza maps. The most recent survey was conducted in the 1990s and still it is not implemented in Bangladesh. This survey is known as the Bangladesh Survey (BS), so the century-old CS maps are still used as the base line corroboration for Revenue and Bangladesh Surveys.

Mauza maps are regarded as invaluable spatial-historical documents and assets which can be integrated with high resolution satellite images and aerial photos with the help of DGPS based ground control point data and can be considered as a milestone for the map-image amity to understand the very dynamic deltaic land systems in Bangladesh. These mauza maps play a significant and detailed role for further study and also help to map the impact of land transformation at mauza level. Digital conversion of these maps can also help in land reform, management, development, planning and environmental monitoring systems in the country.

Anatomy of a mauza map

What does a mauza map look like, what kind of information does it contain? Figure 2-21 is an ideal example, where we can see a number of mauzas with their names. Oalia Mauza is located in the middle of the map with plots boundaries shown. Some mauzas on this map are very big and some are small, with very irregular boundaries reflecting local topographic features. The mauza map shows plot numbers at 16"= 1 mile scale, but not road or land use pattern, or inundation conditions. Figure 2-21 has been captured in the digital format from the paper map.

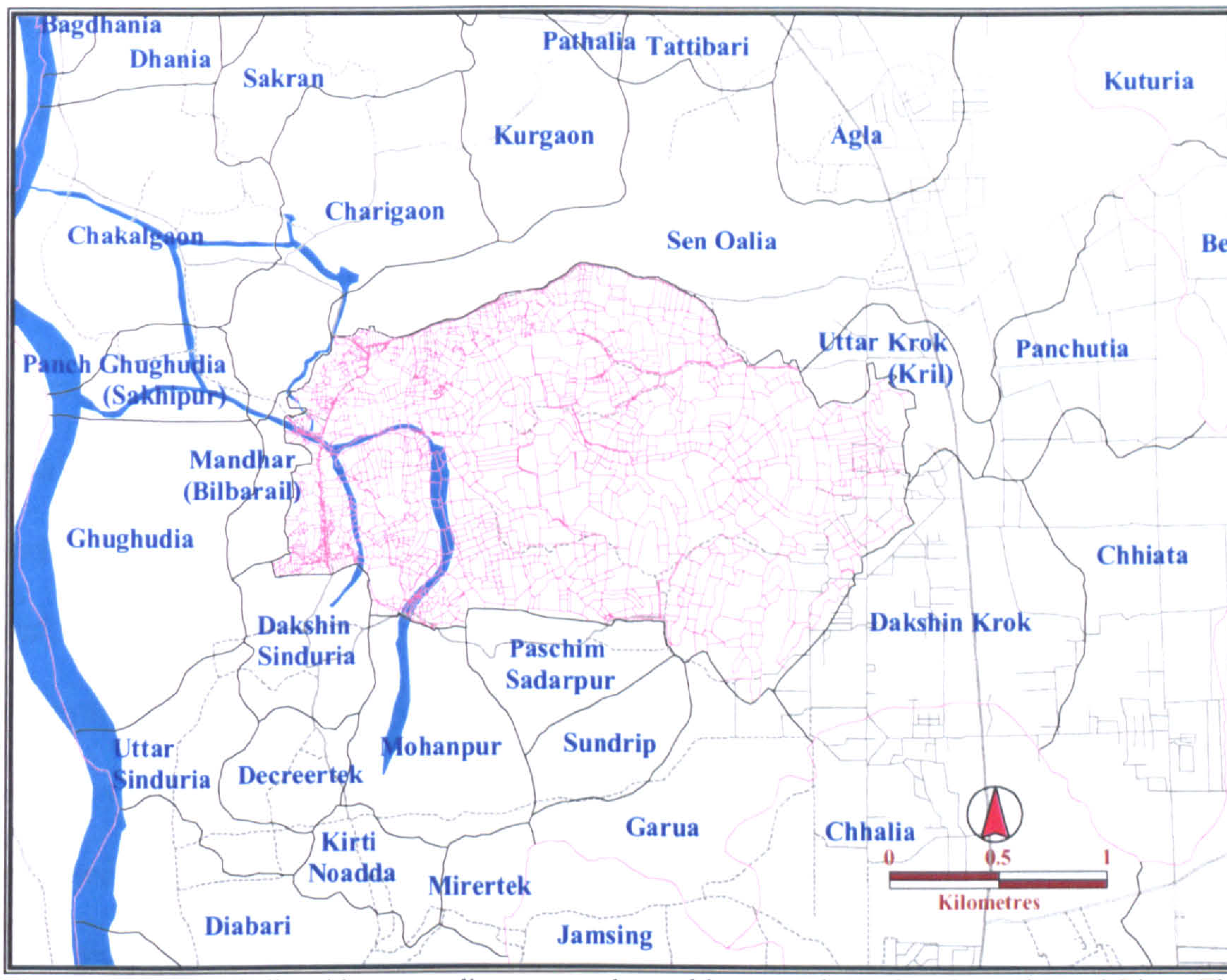


Figure 2-21: Bara Oalia with surrounding mauzas located between the University and Bansi River. The mauza shows plot boundaries, with the smaller and fragmented plots located in the western *chars* and bigger plots in the eastern *chalas*. The time of plot survey was the 1960s and at that time, the mauza's progress was influenced by the Bansi river as seen in the west. But in the east a lot of small road networks are visible; these are the phenomena of the recent decades. We can also see the different sizes and shapes of various neighbouring mauzas with their names. *(Source: compiled by author, 2002)*

Land use Guide Plan (1990):

The map title is '***Master Plan of Savar Area (Phase 1) LU-01'***. It is also known as a '**Landuse Guide Plan'** for both sides of the major roads of the Savar upazila. The map is comprised of 10 sheets. The map was based on a survey implemented by the Prakaushuli Sangsad Limited, a consulting firm, of Dhaka under the guidelines of Rajdhani Unnayan Kartipakkha (RAJUK) during June 1989- December 1989 and was finally updated in February 1990. The jurisdiction of the survey was about one kilometre distance along the both sides of the roads of: (a) the Dhaka-Aricha National Highway (b) the Nabinagar to

EPZ Regional Highways (c) the Savar to Biralia Local Road and (d) the Hemayetpur to Singair Bridge Feeder Road. The scale of the map was equivalent to the usual mauza scale i.e. 1:3,960 or 1 inch equal to 330 feet.

Existing and proposed land uses at plot (based on daag) level were two major themes of the map. The components of the ***existing land use*** were residential area, industrial area, metalled/ semi pucca/ katcha roads, commercial areas, marshy land, river/drainage, ditches/tanks, agricultural land, historical buildings, khas (common property/government) land, unused vacant land, education, land govt agencies, mosque/temple/church, graveyard, eid-gah (prayer fields), health/welfare centre, forest/orchards, study area boundary, mauza boundary, and plot boundary with number. ***The proposed land use*** consisted of residential, rehabilitation zone, industry, agro-industry, industry (expansion restricted), commerce, education, health (welfare), administration, urban services, park/open spaces, golf square/ wood land, stadium, lake/ water bodies, natural drainage, natural environmental zones, warehouses, special uses (national monument/Mausoleum, historical sites), urban deferred, and agricultural land. Details of ***proposed roads*** were also given, for example, primary roads (120 or 60 or 45 metre wide), secondary roads (18 metre wide), local roads (12 or 9 or 6 metre wide) and service roads (3 metre wide). All-important names of remarkable locations were also sited on the map. A detailed map-based report was also attached for planning purposes.

2.4.0. Resolution, Projection and Geocorrection

(a) Relationship amongst Resolutions of Maps and Images

The above databases are shown in Figure 2-22. The figure shows a multifaceted relation among the vector-vector, raster-vector and raster-raster with the help of their spatial and temporal resolutions. Also, the positions of the population census data have also been placed as attributes of the both raster and vector formats. In this Figure, 4 axis are shown: top, bottom, left and right. The top position indicates the decadal temporal resolution since 1950s while the bottom line is the data collection period for the censuses of population (*i.e.* 1951, 1961, 1974, 1981, 1991 and 2001) and agricultural censuses of 1945, 1986 and 1996.

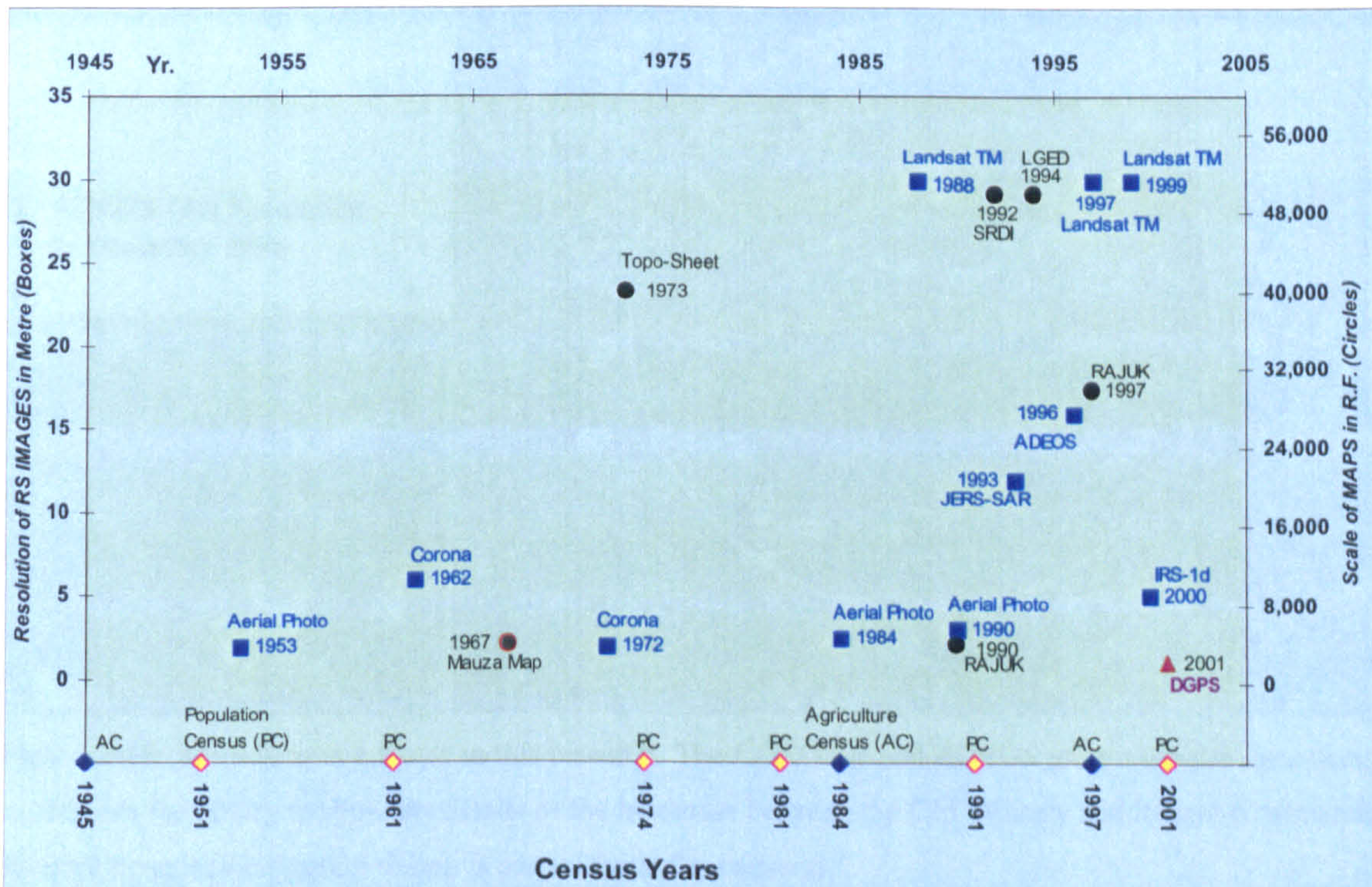
The resolution of the database is based on the existing maps, satellite images, aerial photos, and field based GPS data can be summarised as follows (Figure 2-22). The lower horizontal axis of the graph shows the Population and Agricultural Census years; the upper horizontal axis shows the decennial census intervals in general; the left vertical axis shows the resolution of remote sensing data; and the right vertical axis indicate the R.F. Scale of the maps (*e.g.* 50,000 means 1:50,000). The overall graph shows the interaction between time and resolution of maps and images and their accuracy. It will help to develop an overall idea of the research information bank as well as assessing their quality and diversity. In this graph, the resolution of an image and scale of a map of the same area may be comparable on the basis of their details of the information. The compatibility of 30-40 years of old CORONA spy satellite image, the Aerial Photos, DGPS data have the highest resolution in comparison with the Mauza maps and RAJUK maps of Savar upazila. Landsat imagery is almost equivalent to 1:50,000 scale maps, which are widely used by the Bangladesh government and the private/NGO based planning sectors. Here, the Local Government Engineering Department (LGED), Soil Resources Development Institute (SRDI), Survey of Bangladesh (SOB, Topo-Sheets). ADEOS-AVNIR and JERS-SAR satellite images have a medium range accuracy in this context. Moreover, GPS survey data will also provide a very high quality of *in situ* information of the study area.

Also, this graph indicates general comparatisons between the true meanings of resolution with the conventional map's representative fraction (RF) scale. For example, a 3 metre resolution satellite image holds, in general, 1:4,000 metre conventional map data while a 30 metre remotely sensed image corresponds to a 1:50,000 map scale. The relative temporal resolution has also been shown in the light of census years and data/image collection/acquisition years to understand the time factor properly.

Figure 2-22 presents the compatibility of the data sources in general, which is the prime strength of the research. The existing databases for this thesis are fulfilling the most relevant pre-assumptions set by researchers in this field. Therefore, the current research is based on a very rich variety of compatible sources of maps, censuses and images to develop guidelines and a model.

For example, large scale Mauza and RAJUK plot maps are compatible with high-resolution CORONA films, IRS Satellite images (replicate less than 1:10,000 scale) and black-white and infrared Aerial Photos, whereas LGED, SRDI and RAJUK maps (reflects about 1:30,000 - 1:50,000 RF scale) are well-matched with widely used for medium scale maps ideally used for planning and development guidelines at upazila level in Bangladesh. The above X_1 axis (bottom) shows the survey years of the population and agricultural censuses (diamond shapes) while the X_2 (top) axis shows 5-year interval of the time resolution for this research. The Y_1 axis (left) reflects remotely sensed images by resolution in metres in comparison to the Y_2 axis (right), which is the traditional R.F. (representative fraction e.g. 1:50,000) method used in maps. The graph is a summary of all of the major data sources and it establishes a link between them. Figure 2-23 also demonstrates the quality and detail of high-resolution images in comparison to medium resolution remote sensing data.

Temporal and spatial resolutions of maps and images in comparison with census years



Source: Compiled and integrated by author, 2001

Figure 2-22: A comparison and interrelation amongst the major maps and remotely sensed images is illustrated here to understand spatial and temporal resolutions between conventional map data of the study area (black circles) and/or air or space borne images (blue boxes).

Resolution Comparison between CORONA and ADEOS of Savar Municipal Area

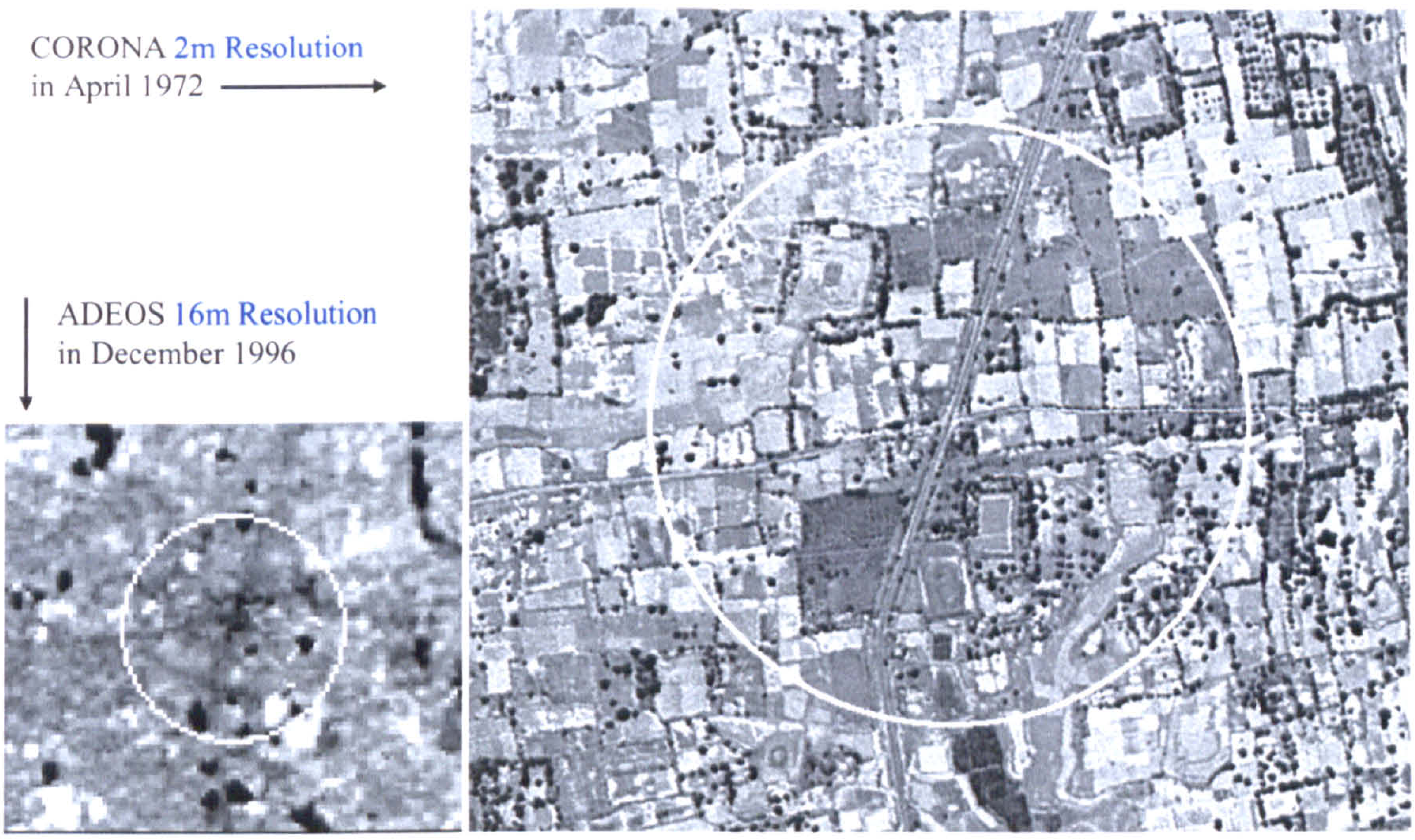


Figure 2-23: Resolution is a factor in this research. The CORONA and ADEOS gave a unique opportunity to compare the ability to show the details of the landmass between the Old Military and Recent Commercial Satellite Images (the location shown is part of Savar Paurashava).

(b) Projection Parameters

For all GIS, GPS and Geometric Correction of Images, the parameters shown in Table 2-15 are commonly used in Bangladesh. EGIS, a famous non-government organisation, uses the BTM (Bangladesh Transverse Marcator) and LGED, a leading government GIS centre, use Lambert Conformal Conic Projection. However, to match the dataset with the government purposes, I used the parameters of LGED.

(c) Geocorrection and Georeferencing of Maps and Images

PCI GCPWorks software has been used for image registration, mosaicking, geometric correction and projection in this research as all of the collected images were in raw format

(Figure 2-24). GCPWorks is a stand alone application to import image data from various sources, tie it down to a georeferenced image, and perform registration and mosaicking functions. GCPWorks offers an intuitive, powerful interface to all these steps to improve productivity in an experimental or production environment. The following options are available in the module, the checked are taken finally in the current research context. When "Full Processing" is selected the user is expected to establish a transformation using both GCPs and a mathematical model as well as perform a registration of the image. This option is the most traditional and a good default. The thin Plate Spline mathematical model is also computed based on a set of GCPs, but is always exact at each of the GCPs. The "Vectors" correction process is used to tie down an uncorrected image to a set of georeferenced vectors of the same area. Additionally, a backdrop set of imagery may be selected and displayed in the georeferenced image window.

Table 2-15: Projection Parameters used in Bangladesh

Input Coordinate System:	BTM of EGIS	LCC of LGED
Name:	Custom	Custom
POSC:	-1	-1
Unit:	Metre	Metre
Geographic CSYS:	GCS_Everest_Bangladesh	GCS_Everest_1830
Datum:	D_Everest_Bangladesh	D_Everest_1830
Prime Meridian:	Greenwich	Greenwich
False Easting:	500000	2743185.699
False Northing:	-2000000	914395.233
Base Projection:	Transverse_Mercator	Lambert_Conformal_Conic
Central_Meridian:	90.00	90.00
Central_Parallel:	0.00	26.00
Scale_Factor:	0.9996	-------
Standard_Parallel_1:	-------	23.15
Standard_Parallel_2:	-------	28.80

Unpublished sources from LGED and EGIS of Bangladesh, 1999

Nearest neighbour interpolation or Resampling Mode determines the grey level from the closest pixel to the specified input coordinates, and assigns that value to the output coordinates.

The Setup used for GCPWorks of the PCI Software

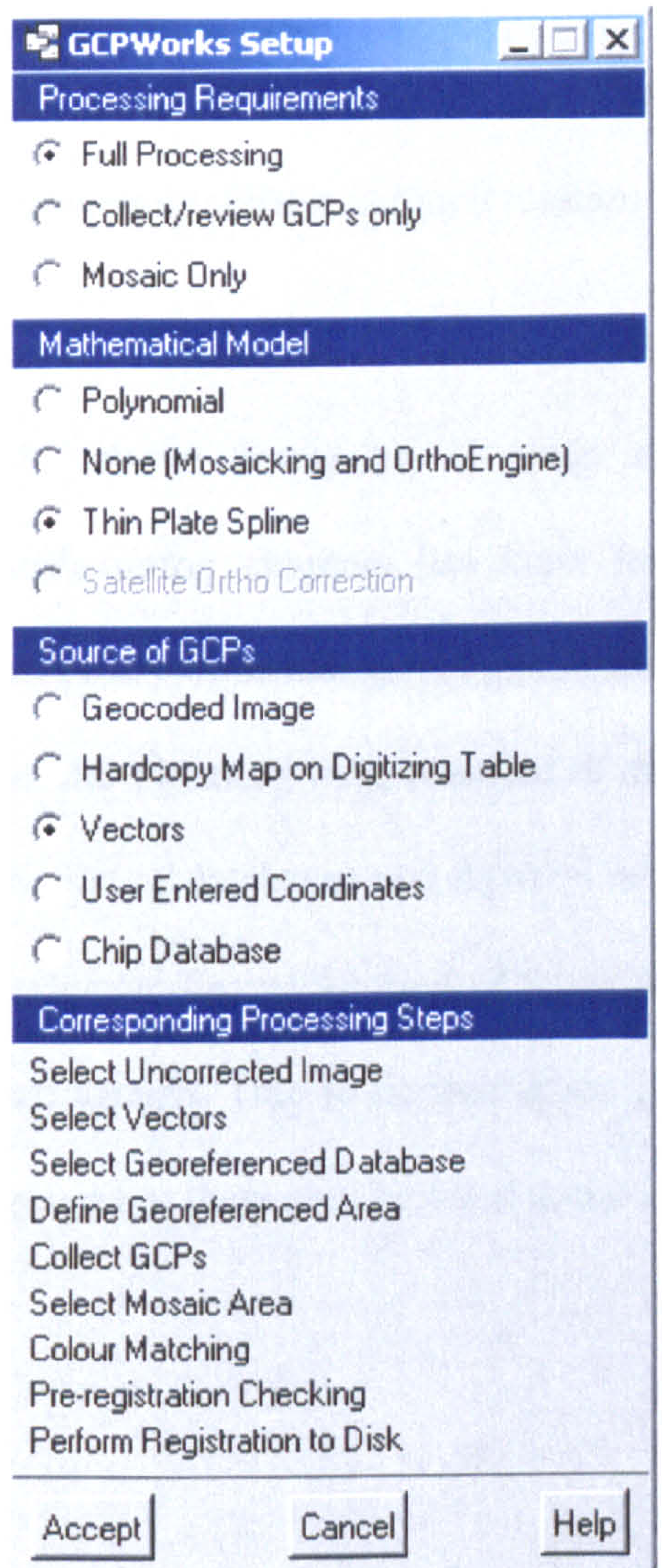


Figure 2-24: Steps for image processing

1. **Select Uncorrected Image** (e.g CORONARAW.img):, the raw satellite image;

2. **Select Vector** (e.g. GCP_DGPS.e00): The Ground Control Point data have been created using sub-metre accuracy of DGPS surveying during the fieldwork. The data converted as ArcInfo interchange file. Database Vector Segment was the Arc Layer. The Vector layer offers a high quality geometric correction opportunity.

3. **Select Geo-referenced Database or Image** (e.g IRS_00_Base.img): The image is primarily geo-referenced on the basis of DGPS Survey GCPs and used as background for all image calibrations as an 8-bit single channel. The option gives an extra layer to see the images beneath the vector layer as an already geocoded image.

4. **Define Geo-referenced Area:** The area is defined based on the maximum extent of the study area or in some cases photo frames or films are used depending on the circumstances;

5. **Collect GCPs:** Total 342 GCPs were taken for Savar upazila. In addition, the road drawn by DGPS technique was also complemented as GCPs, which was countless. For the all images, unique GCPs were used in order to maintain a common standard.

6. **Select Mosaic Area:** The best possible area was taken during mosaic.

7. **Colour Matching:** the original colour or grey scale as acquired from the raw data was kept.

8. **Pre-registration Checking**: Registration points were checked before the final task.

9. **Perform Registration to Disk:** Finally a new image called CORONADGPS.img have been created using the 'Nearest Neighbour' resampling mode. Other modes were set to default.

Because it does not alter the grey level value, a nearest neighbour interpolation is preferred if the spectral characteristics of the original imagery need to be retained, if classification will follow the registration, or if a classified image is to be resampled. Nearest neighbour interpolation introduces a small error into the newly registered image. The image may be offset spatially by up to 1/2 a pixel, causing a jagged or blocky appearance if there is much rotation or scale change.

2.5.0. Conclusion

The above discussion of study area and its databases and images relevant to the forthcoming chapters has been for the purpose of the establishing a background of necessary information. All the information has had to be converted into digital format and careful planning were required to make them compatible to each other. I have established the list of databases and datasets required for this study and this has been valuable for an understanding of the land of Savar with its rich physical diversity and also richness of data and images. Due to limited space I have not discussed the attributes of each dataset and image but these will be cited in the following chapters as and when appropriate.

Chapter 3

CHAPTER 3: INTERPRETATION OF LAND FEATURES AND DECENNIAL TRANSFORMATIONS

3.1.0. Introduction

The current chapter is primarily be based on satellite images and aerial photos at a decennial scale between 1951 and 2001. The characteristics of each type of imagery have been presented in the previous chapter. The aim of the chapter is to identify the individual features of land, their characteristics, using interpretation techniques based on the six decade series of images. The chapter is not only intended to identify the land features but also to help with documented features and evidence, reconstructing the history of decennial phases of transformation since the 1950s. Land feature identification using remotely sensed images will help us to establish a history phase by phase. The aim of the chapter is also to create a background and detailed context by interpreting and gathering information to integrate with social (e.g. population census and land value) data for the forthcoming chapters and also to develop an image interpretation key for the entire study.

Savar upazila has rapidly changing land features and surface cover and a very complex physiography. For example, the upazila was mainly a forested area and covered almost 80 percent of the chala land before 1950s, but now less than one percent remains. There were no road transport systems within the area 50 years ago and no connections to other cities by road. The river was the only mode of transport network and the traditional bullock-cart was the only land based commodity carrier. Savar's physiographical complexity comes from being in a zone adjoining major geological structures such as the Pleistocene terrace of the Madhupur tracts, or *gaarh* dissected by *bydes*, and active floodplain like the Dhaleshwari catchments area including *chars* and *kanda*. Therefore, the area is full of diversified land features and phenomena with a rapidly changing status. In this chapter each of the individual land features responsible for transformation have been highlighted with local terms and names.

3.2.0. Methodology

(a) Elements of Visual Interpretation

For the single or grey band high resolution (less than 6 metres) air and space photography such as panchromatic images, the most powerful analysis technique is to use the human brain. Our brains can interpret the relevant context rather efficiently. An experienced photographic interpreter is able to extract information much more effectively than any automated computer based method. As we already know, in this research scanned CORONA satellite panoramic film, black-&-white or infrared aerial photos and IRS images have been interpreted. To the best of my knowledge, my usage of CORONA, and the comparison of IRS images with CORONA is the first of its kind in South Asia.

We need to have an understanding of several basic characteristics of features shown on images or photos. But depending on the field experience and research aims, the techniques of interpretation may vary. In most cases shape, size, season, pattern, tone (or hue), texture, shadows, site and association are the most common parameters. Phenomena marked by a star (*) below are additional features used by the author. Here, the elements of photography, images and films are explained using examples given in the present chapter.

(1) **Shape** refers to the general form, configuration, or periphery of individual objects. Here for example, we identify any *byde* in Savar by its unique shape, which dissects *chala*-land. Figure 3-19 shows how a village on *chala* land is encompassed by its surrounding narrow passage-shaped *bydes*.

(2) **Size or scale** of objects on photographs must be considered in the context of the ground resolution of the imagery. A river and a *khal* can be easily misinterpreted

if the relative size is unknown in the context of Bangladesh (Figures 3-25 and 3-29).

(3) **Pattern** reflects the spatial arrangement of features. Dissected bydes were the most important landmarks encircled by *shaal* forest. Moreover, linear arrangements of planted jackfruits orchards are very different to that of *shaal* forest (Figures 3-3 and 3-12).

(4) **Tone** (or hue) refers to the relative brightness of object on photos. For example, the soil of the chala land is relatively brighter when compared to the *chwak* land due to the variation of moisture content in the soil (Figure 3-4). For multi-spectral images, colour can also be included in this category.

(5) **Texture** is the frequency of tonal change on the image. It determines the overall smoothness or coarseness of image features. The most important instance for the study area is identification of forest cover types. The bamboo forest and shaal forest (Figures 3-11 for Bamboos and 3-7 for *Shaal)* can be distinguished by the smoothness and coarseness of their appearance respectively.

(6) **Shadow** is an important element of interpretation for elevated land and for any topographic feature. For example, the length of shadow cast depends on the position of the sun at the moment the image was acquired. Savar is not a hilly area and does not have a significant number of high rise buildings but its naturally created *chala* lands have elevated villages in comparison to the low altitude of *chars* named *kandi*, which cast shadows (Figure 3-24).

(7) **Site** refers to topographic or geographic location and is a particularly important aid in the identification of vegetation type. Jackfruit cannot tolerate standing water more than a few weeks. So on the medium or low land, the presence of jackfruit is not possible (Figure 3-5).

(8) ***Season** is also a big factor in identifying land types. During the flood period (Jul-Sept), the medium high to the very low land could be misinterpreted as a low land on the big floodplain like Bangladesh. As little as a one metre difference in height can be a big factor for land classification and agricultural purpose. For example, the *chwaks* and *chars* go under water in the monsoon and are not again visible as agricultural land for several months (Figures 3-4 and 3-5). Therefore, if we want to calculate the total area of cropped in the wet season, care is needed to avoid being totally wrong and misguided.

(9) ***Length** and **Sinuosity**. The fast highway (Figure 3-16) is relatively straighter and longer than local roads. The national highway is especially different from the local roads. CORONA 1962 photos show the early stage of national highway and the local road network, though both of them were still only exposed soil. The lower sinuosity is characteristic of the national highway while greater sinuosity reflects the routes used as footpaths or for bullock-carts.

(10) **Association** refers to the occurrence of certain features in relation to others. Figure 3-6 demonstrates, for instance, that *kandis* are highly associated with *chars* and their creation is related with the active river system. In recent years brickfields have developed on *chwaks* as Figure 3-37 illustrates.

(11) ***History** refers to the gradual change of the land. The current land features contain the history of the past and elements are sometimes visible in the images. For instance, in 1950s Old Musurikhola village was on the Map of Savar, but it was eroded by the Dhaleshwari river. The Musurikhola village we now see, is in a new place, with a new shape for a new generation. Figure 3-25 illustrates this extraordinary example. Without the image sequence, it would be difficult to visualise such a change.

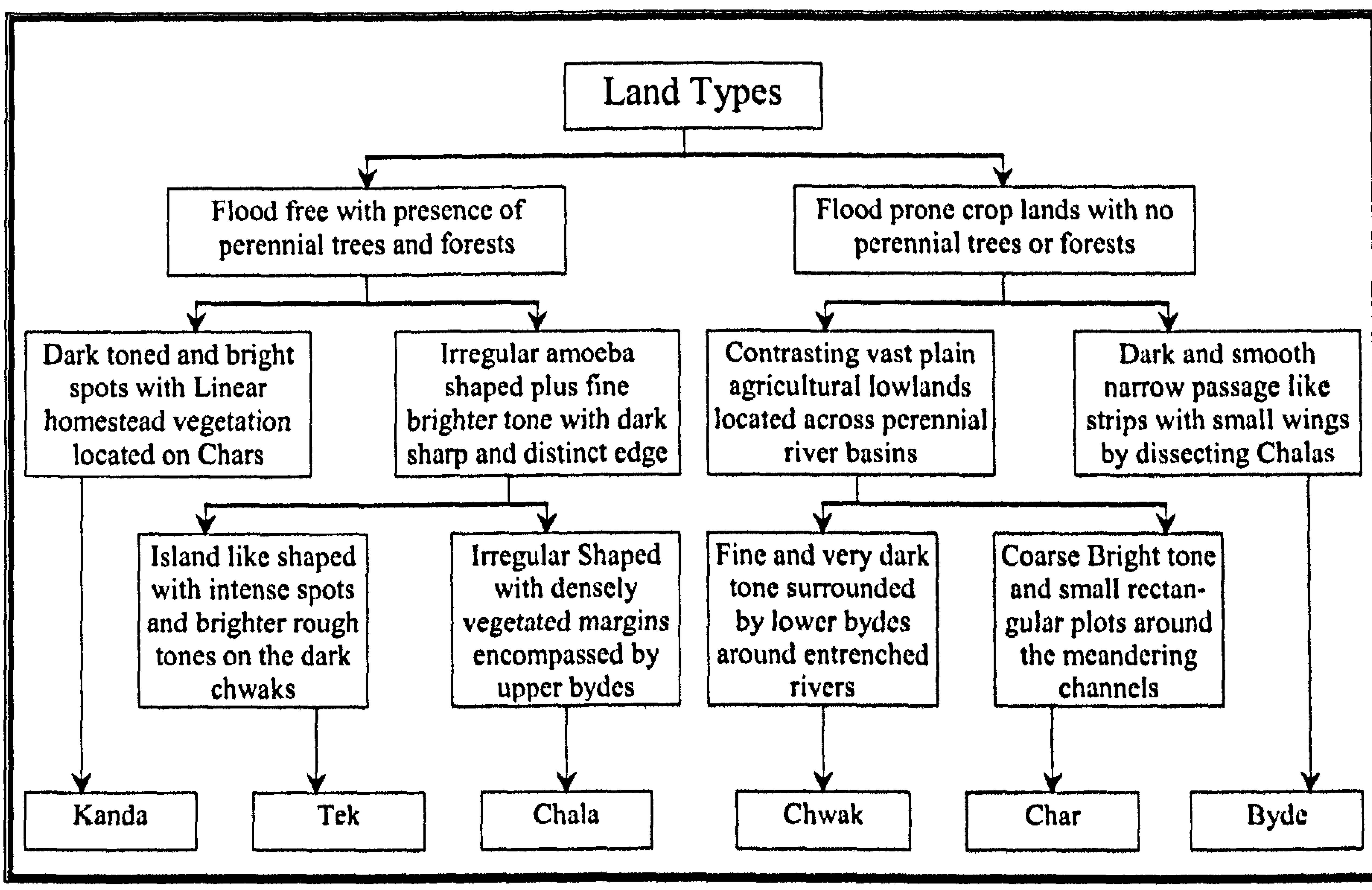
(12) ***Human interference** can also be actively important in identifying some features. Where natural phenomena are given a more geometrical shape. If we see any box, rectangular, line, smooth curve, polyline, round etc shapes on a land we can take them to be, in general, due to human intervention. For example, some bydes are changed over time due to development activities and now have been converted into farmland; as in Figure 3-13.

(13) The ***Sensor** is also a parameter to see certain features in a certain way. For example, some water bodies in CORONA KH4 and KH4b are dissimilar, and there is even more divergence with aerial photos (Figure 3-17). Some features are not properly visible to one sensor while being very clear to others depending on the specification and height of the space- or air-craft.

(14) ***Margin or edge** refers to the periphery of a poly-shape feature, for instance, *beel*, *sarobar* and *jheel*. All of them have emerged from *bydes* but have different margins of the water bodies. *Beels* have rough margins with seasonally retreating behaviour, while *sarobars* and *jheels* has smooth and stable margins. Again, between *sarobars* and *jheels*, *sarobars* are smooth and *jheels* have the sharp margins (see Figures 3-30 for *beel*, 3-32 for *sarobar* and 3-26 for *jheel*).

(b) Dichotomous Key

To help understand the interpretation techniques properly an interpretation key is sited here (Figure 3-1) as an example to understand the steps that were followed. The flow chart shows of features related to land types in the context of the study area. Lillesand and Kiefer (1999) have illustrated a similar strategy to determine the fruit and nut crops for small and large tree crowns in the Sacramento Valley, California. They comment on the difficulties of dichotomous keys for landform identification, but the use of CORONA film for Savar has been more successful.



Source: Field verifications and experience, 2001

Figure 3-1: As an example, dichotomous CORONA KH-4b interpretation key to land types of Savar upazila are shown designed for use with 1:10,000 scale panoramic reconnaissance photos. The key can also be used for most of the high-resolution panchromatic images such as IKONOS and IRS data and B/W or IR aerial photos.

(c) Field Visit and Interviewing Local People

I have visited the land features identified and verified these by observation. The DGPS technology was used to locate features for ground truthing. In most cases, I talked to the local villagers if there was a query about any feature I made a note. Also, in some cases, I photographed and videoed sites for further reference.

(d) Primary Guidelines for Interpretations

The following section has two basic aims. The first aim is to identify major features from the images and the second aim is to see the impact of time and variation of the information captured on imagery from different sensors of the same area. So every subsection will use six clips from the main database of Savar upazila. Due to practical constraints, for several features one clip out of six is missing. In these cases either the images were not available or the government did not made the photo frames available, in the name of national security. However, all of the missing clips are covered by air photos. IRS 2000 and CORONA 1962 and 1972 are available for whole study area.

The Scale and orientation of the north line for the most of the clips are shown in the Figure 3-2. The following interpretation techniques will help us to find the appropriate features on the basis of their characteristics and field experience. The east-west and south-west extents are 1.27 km and 0.79 km long. The average area of any clip is approximately one square kilometre.

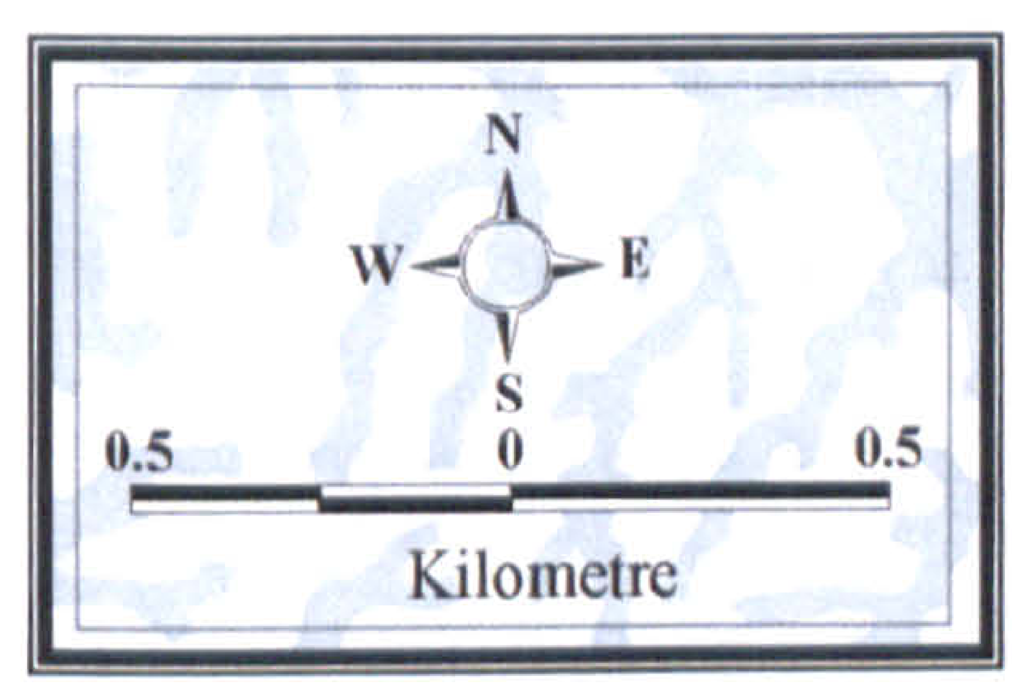


Figure 3-2: Scale and north line for the each clip shown in this chapter will follow the same unless otherwise stated

The chapter has been organised according to feature themes under broad categories. Each theme focuses on a particular land type or feature. All of the themes are discussed with illustrations and each location contains 5-6 frames.

A two-fold analysis of particular features is given here. A description of the site will be given in the first half where the background to each feature is specified. The interpretation technique will be elaborated here and how the individual features have been changed or are unchanged will be explained. In the second part, an account is given of the location and the local name of the site and its brief history.

Guidelines for integrating the image information into a GIS environment will be given to facilitate the addition of attributes for land management, taxation, development monitoring and so on. The importance of CORONA photography and IRS images will also be revealed, including traditional aerial photos. CORONA and aerial photos have not been verified in these physiographic and transitional contexts before. It will also be a unique opportunity to see how the same field can be seen through various air and space borne sensors. One sensor may complement others in understanding the particular land features more accurately.

Some of the clipped features may not be clearly visible in printed form because of digital scanning, the quality of the printer used and its resolution and scale. Better quality can be obtained by printing at a larger scale on a photo-quality paper using a high dpi printer. This would produce an image that is much clearer and more easily interpreted. Here the clips are given as primary guidelines and not as final outputs.

This chapter also focuses on the use of local and indigenous knowledge regarding land feature identification. Sincere efforts have been made to integrate and incorporate field-based skills with the standard classifications and remote sensing techniques. Local terms used in this chapter are recorded in *italic*, the meanings and their meanings are explained in the glossary section at the end. The closest possible English term is used in the text.

3.3.0. Feature Interpretation and Reconstructing the Past (RP)

The identified features are classed into seven broad categories and each category has several subcategories. The classification is based on the vertical photography and from field experience. The details are: land types including *chalas*, *bydes*, *chwaks*, *chars* and *kandas*; vegetation cover including *shaal-baan*, *kathal-bagan*, *bansh-jhar*, *ghash-khila*, *fausholi-jomi*, homestead vegetation, and sometimes no vegetation at all; road networks including mainly *pucca* roads and *katcha* roads; rural territories including *gaons*, *dias* and *kandis*; pro-urban developments including the Jatiya Smritishaudha (National Monument), *paurashava*, planned towns and housing projects; water bodies including *sarobars*, *dobas*, *pukurs*, rivers, *shapla-jheels*, and *khals*; and Industrial belts like foreign and locally invested industrial belts and brickfields. Identifying plot boundaries to integrate with *daag* numbers is also vital for further analysis. A step by step description of all of the features mentioned is given below with short notes and examples.

3.3.1. Land Types

Land types are very important in the context of Bangladesh. It is one of the lowest-lying countries in the world and each year it is flooded during the monsoon period. Flooding is the most important phenomenon in the life of the country. The height of floodwater influences many social and physical phenomena. Land type is one of the most important of these. Only a few metres of variation in floodwater depth creates five major classes of land. These are 'high land', 'medium highland', 'medium lowland' and 'lowland'. *Chala*, *chwak* and *bydes* are interrelated features as the part of Pleistocene terraces while *kandas* are dependent on surrounding *chars* as a part of active river floodplain. Savar upazila can be classified in to five categories using local names and land types Table 3-1.

Table 3-1: Land types of Savar upazila and their basic characteristic with local names

	Local Name	Land types & soils (broadly)	Inundation	Common locations in Savar
(a)	*Chala/Taan*	Highland, Friable Clay	Flood free	Main landmass of Madhupur Track
(b)	*Tek*	Highland, Friable Clay	Flood free	On *Chwaks* like an island
(c)	*Kanda*	Medium High, Silty loam	0-1 months	Dhaleshwari Natural Levees
(d)	*Byde*	Medium Low, Clayey loam	3-5 months	In and around Madhupur Track
(e)	*Char/Naaljomi*	Lowland, Sandy loam	4-6 months	Dhaleshwari River Floodplains
(f)	*Chwak*	Very lowland, Clayey loam	6-7 months	Valley of Turag River

Source: Interviewing during fieldwork, 2001 and image interpretations.

On the basis of the above classification, we can now identify land types using the remotely sensed images interpretation technique. Each floodplain feature will be illustrated with relevant image clips or frames.

(a) Chalas: Madhupur Tract/Gaarh

Interpretation Techniques: The chalas are shaped like irregular polygons and are dissected by bydes. Those of the largest size, as well as the brightest tone with a very fine texture, have very dry soil. The grid-like pattern and margins of chala contrast strongly with neighbouring land features. *Chala* is highly associated with shaal forests, jackfruit orchards and homestead vegetation. Figure 3-3 shows a typical example of traditional *chala* land. The land with orchards shows the extent of *chala* land, while the land with no orchards indicates the limit of the feature that means the transition to bydes. In both dry and wet seasons, *chalas* are free from flooding and remain as bright features if there is no vegetation.

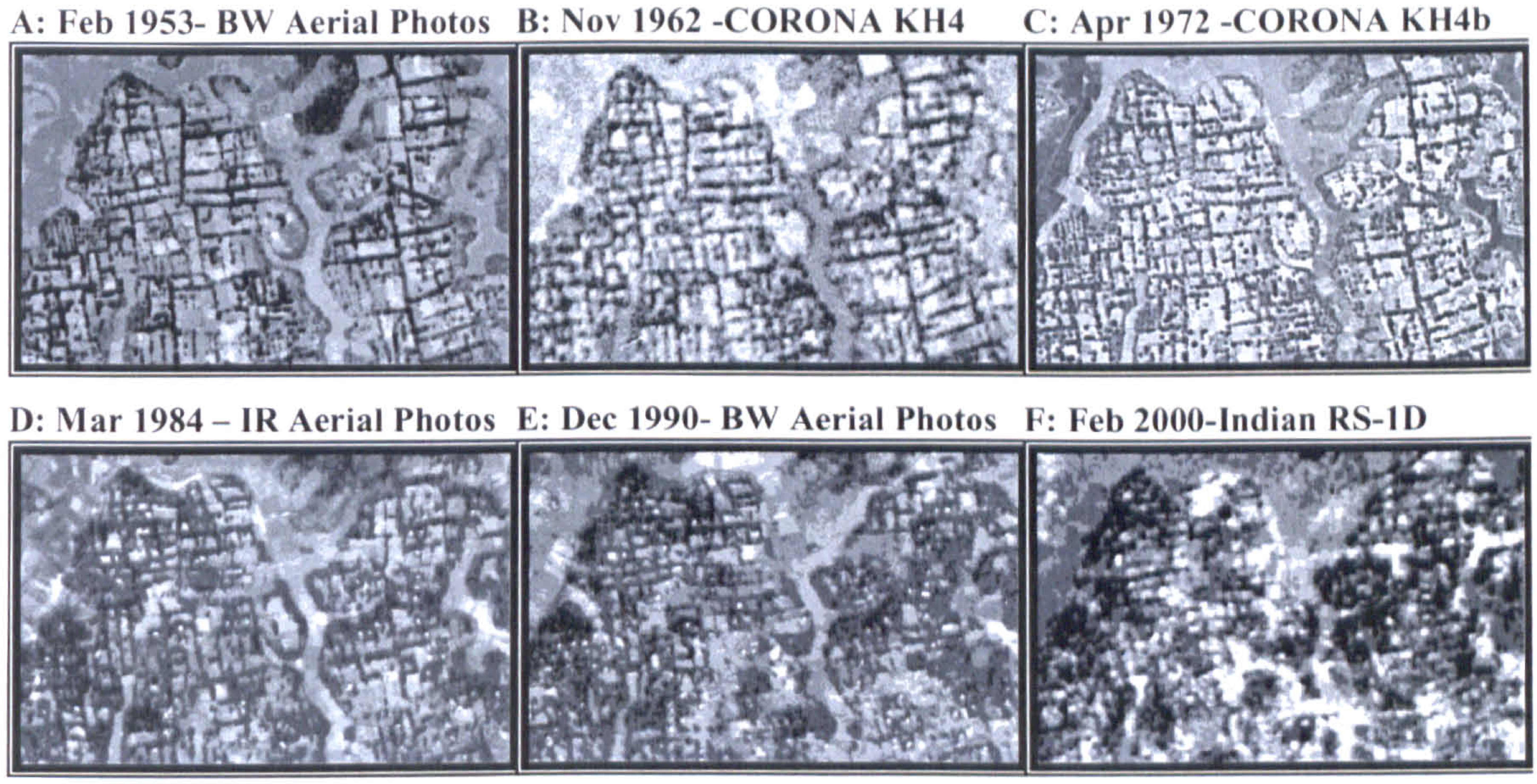


Figure 3-3. Chala land in Deogaon village shows the presence of orchards bounded with *bydes* having no orchards or perennial trees. *Bydes* dissect the *chala* lands with narrow channels and extended wings on both sides.

Background and Reconstructing the Past: As an example, Figure 3-3 illustrates the land cover of *chalas*. In clips A, B and C, the land was partially covered by dark objects which are jackfruit orchards and since the 1980s the images have contained small sharp spots identified as rural settlements with a range of homestead vegetation. In the last frame, F, the southern chala have been affected due to orchard grubbing and earth works. The neighbouring bydes are unaffected here, and cut the chalas off from each other. To expand a village without a good road communication is a slow process as shown in the figure. Most of the land cover and land use has changed in Savar upazila over the *chala* lands and details will be given in the following sections.

(b) Teks: Located by Chwak, Like an Island

Interpretation Techniques: *Tek* is a landmass, which has similar characteristics to *chala* but is different in its location. It is like an island on a *chwak* and generally has a round shape. No *bydes* dissect it, as it is a relatively small body. A *dia* is a special kind of village which is located on a *tek*. *Dia* means village while *tek* refers to the land.

Background and Reconstructing the Past: Generally *teks* were part of a deep *shaal* forest before human intervention. This is very stable land and suitable for an agro-based village. In Figure 3-23, a typical *tek* land is demonstrated. The *tek* is a very stable landmass in comparison to *kanda* or natural levées. Due to tectonic activities during Pleistocene period, *chala* and *tek* lands emerged together. That is why in Bangladesh *teks* are located in the tract regions like Madhupur *Gaarh*, which encompasses Savar.

(c) Bydes: Narrow Sloped Passages Dissect Madhupur Tract

Interpretation Techniques: This feature, shown in Figure 3-3, dissects the chala land and has no orchards or trees, but a very smooth texture and a relatively brighter tone. The river channel-like byde gradually disappears to chala at one end and keeps contact with permanent water bodies or low land at the other end. Each core byde has several small wings. Due to low moisture content, the upper *byde* is brighter than the lower byde. In the wet season bydes fill with water and can be used as navigable routes for several months just like a river. The margin of a *byde* is most likely chala lands and is connected with the relatively darker tone part of a water body. The edges of *bydes* are very smooth and most of the highland villages are very close (only a few metres away) to it just like a ribbon. The width of a *byde* is several hundred metres and the total length including its wings is at least several kilometres. Most of its boundaries are shared with chalas.

Background and Reconstructing the Past: Most of the bydes in Savar upazila are used for Boro Cropping in the dry season after the water recedes in early November. Between the 1950s and the 1970s, this was the only land use of this land feature. Due to its natural fertility, most of the agro-based villages were very close. The bydes can be classified as upper byde and lower byde. The land use of lower byde is still pro-agricultural but the upper byde land use is often changing as settlements impinge. Bydes are affected by the construction of roads, so the free flow of water may be limited and some bydes are now used as industrial wasteland. For example, the western byde bordering the EPZ, known as Bansbari *byde*, is now a dump for liquid chemicals and due to road construction, the mouths of the byde have been obstructed, so the very fertile byde land was full of stagnant water within a decade of the commissioning of the EPZ. The seasonally flooded *byde* is now a perennial beel. Some bydes are properly managed and upgraded to attractive lakes, such as the Jahangirnagar University Campus *sarobars* and National Monument *jheels* (see Figures 3-32 and 3-26 respectively).

(d) Chwaks: Mainly in the Turag Basin

Interpretation Techniques: Here, the darkest tone is due to high moisture content and the smoothest textures are due to the intense presence of organic and clay materials and dissection with narrow or wide channels known as *chwak.* The *chala* margins determine its shape and the coverage depends on the width of river the valley. The valley, in any context, is very distinctive from the neighbouring features and there is no chance of misinterpretation. Most *chwaks* are integrated parts of the valley.

Background and Reconstructing the Past: The depressed part of the Turag Valley is known as *boro-jomi* because the area is suitable for *boro* paddy cultivation in the rabi season. The area belongs to the eastern border of Savar upazila, adjoining the western part of Dhaka Metropolitan Area (DMA). In the wet season, the area goes under water for more than 5 months with 3-5 metres depth of water. The clips presented in Figure 3-4 are a fraction of the whole scenario. The valley is a plain and is dissected by the narrow channels as shown below. Due to the embankment built in the east in 1990, the valley is now connected with a road as well as the historical Turag river. The main difference between the beels and the valley is that the water is not perennial in nature, so it is cultivable in the *rabi* season. The *boro* crop is cultivated here in the dry season.

In recent years, the depressed area has been utilised as brickfields on both sides of the Dhaka-Aricha Highway (Figure 3-37) and newly built Ashulia Highway.

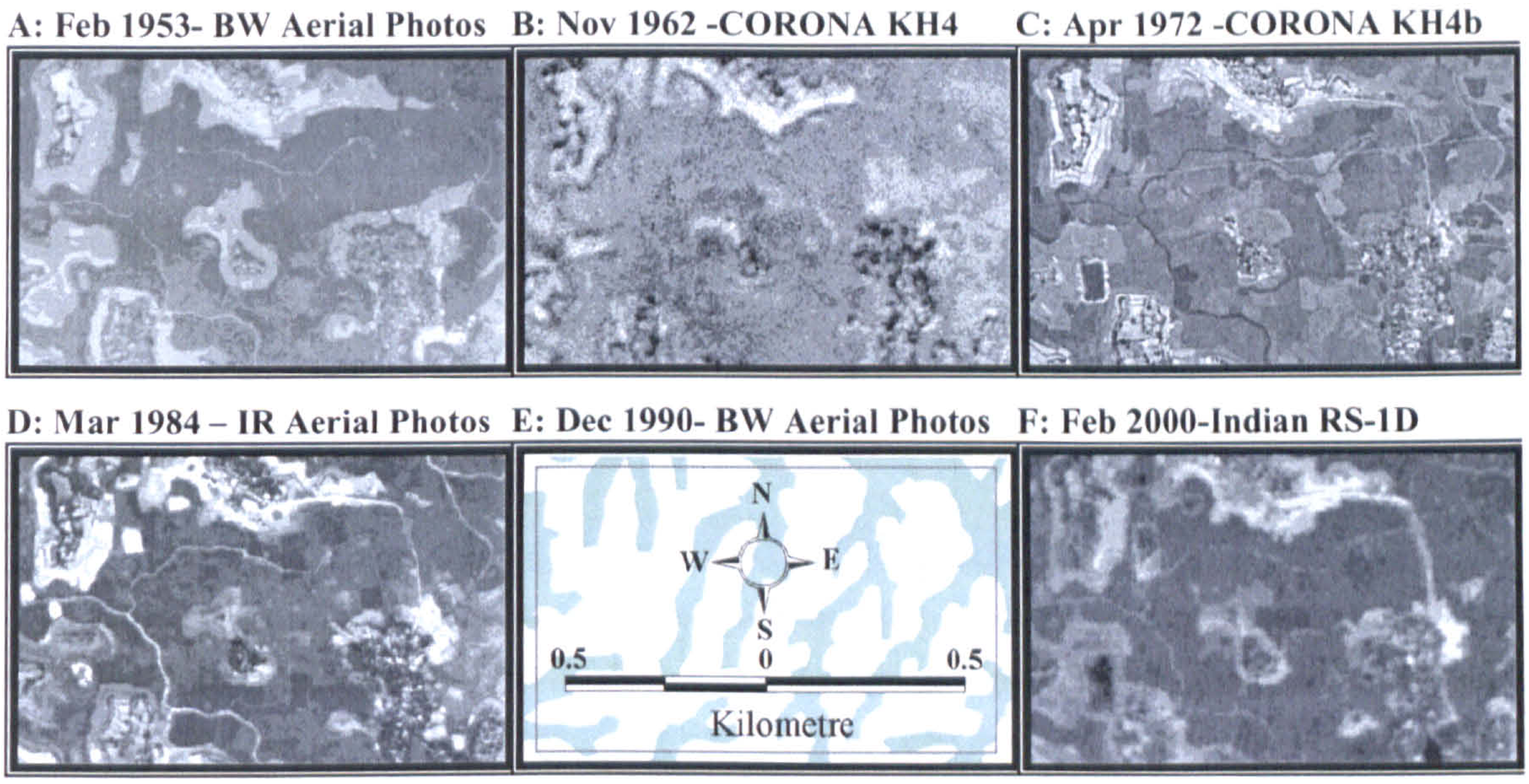


Figure 3-4. This *Chwak* is located in the southern Bara Kakur *Mauza*. All clips show the flatness of the *chwak* and its association with neighbouring *chalas*. In the middle of *chwak* a few metres narrow channel flows with a bright reflectance though clips C illustrated the reverse tone. The clip 1962 shows the whole area is inundated shallowly as it was take in late monsoon. The 1990 clip is not available.

(e) Chars: Mainly in the Dhaleshwari Active Floodplains

Interpretation Techniques: The brightest object with no vegetation cover (Figure 3-5) is known as a *char*. The *chars* are associated with rivers and natural levees. There is no *byde* in this feature. The many small square boxes or rectangular shapes indicate the plot boundaries. Due to a high content of sand, the soil texture of *chars* is relatively coarser than the *byde*. The area is at high risk of riverbank erosion and extreme floods and therefore no other type of land use is possible in this area.

Background and Reconstructing the Past: Though in Savar, the vulnerable floodplain area is referred to as *char* land but in most cases the low-lying countryside is known as *naaljomi*. Chars are very active and are washed by floodwater every year during the rainy season.

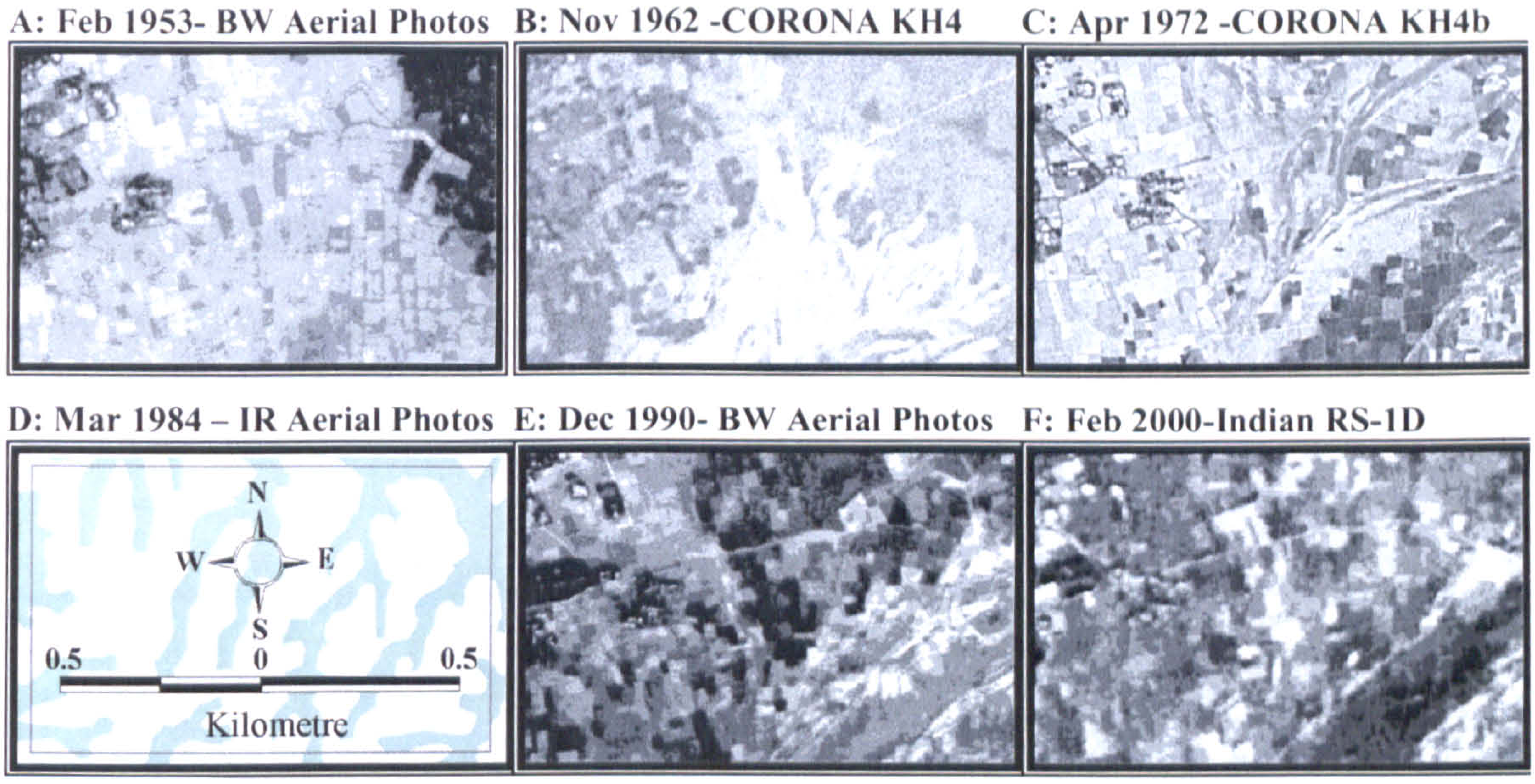


Figure 3-5: Western part of Bilamalia *mauza* indicates an active floodplain known as *char*. The feature is highly vulnerable to flooding and its surface cover changes each year. In wet conditions, the feature reflects as a dark tone, but in dry conditions, it is the brightest land cover as new sands or sandy loam top-layers dominate the feature. The 1984 clip is not available.

(f) Kanda: Natural Levées of Dhaleshwari Floodplain

Interpretation Techniques: A very dark line and an irregular small object seen on a *chars* are known as *kanda*. A *Kanda* is, most likely, occupied by the villages and has homestead vegetation (Figure 3-6); therefore it is easily identifiable for its contrasting presence. The size is very small in the context of its host *char* or active flood plain. The *kanda* is highly associated with the surrounding *chars* or floodplains. Figure 3-6 illustrates the presence of natural levées. The texture is coarse with a number of small and bright spots (roofs of the settlements known as *tiner-chaal*). The nearby smooth textured objects are depressed land containing water. A road has connected the bydes. Some *kandas* are a few kilometres long and known as *kandi*. *Kanda* indicates the land, while *kandi* indicates the villages on natural levées. A *kanda* may or may not have population but in *kandi* there must be a populated village or *para*. In most cases, natural levées are isolated from each other and follow the bank of an active or abandoned river course. Figure 3-25 is an additional example.

Background and Reconstructing the Past: Figure 3-24 shows the location of a *kanda* encompassed by *chars*. From the 1950s to the 1990s the situation of the *kandi* remained the same. But near the *kanda*, a housing society has taken steps to develop land, so in clip 2000, two bright objects are also seen here as an addition. Since the 1960s, the levées have been connected by roads.

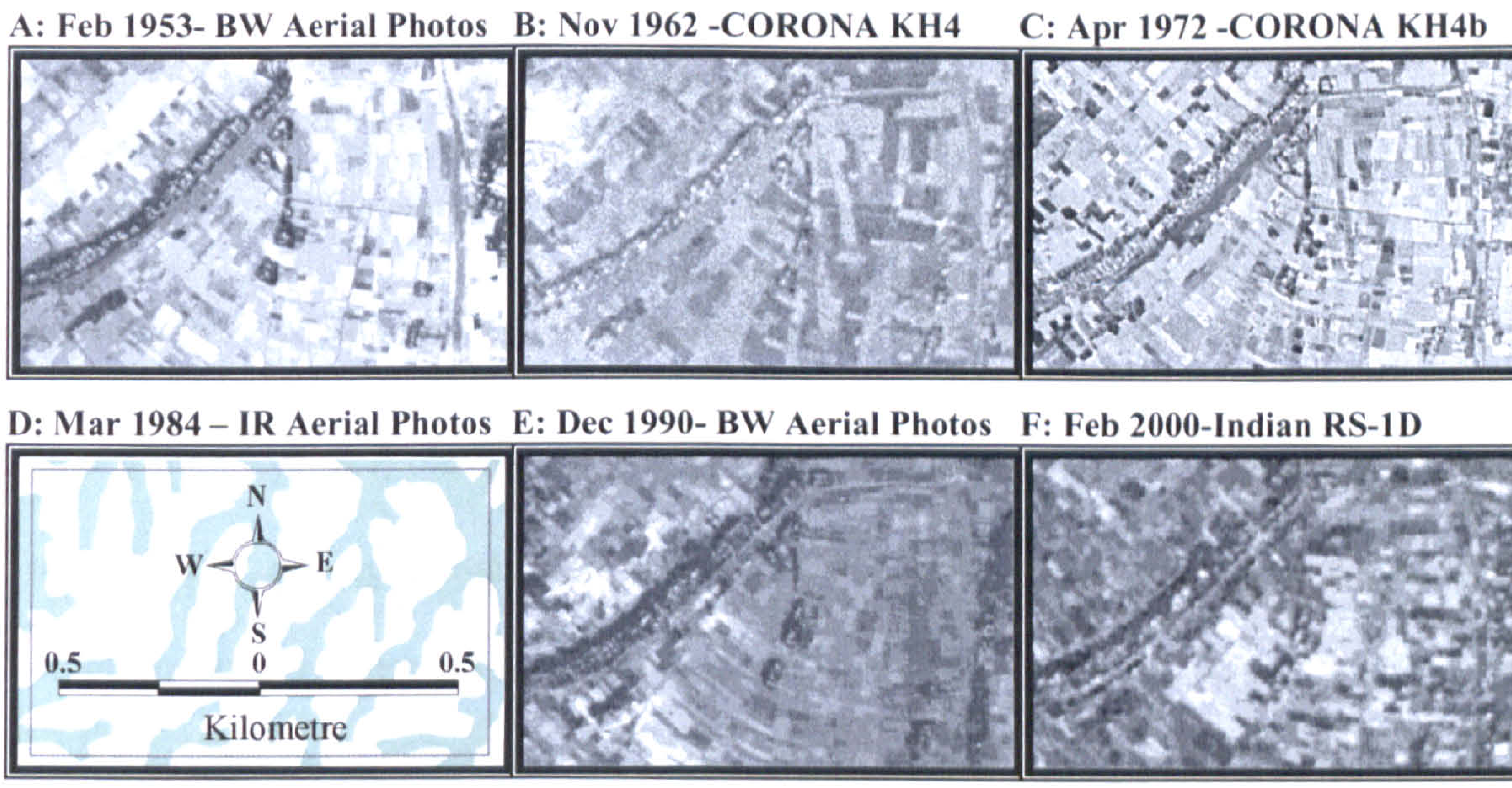


Figure 3-6: *Kandi* of Chunar Char *mauza* shows an association of *char* and *kanda*. In an active flood plain area near the Dhaleshwari River, the linear shaped feature extended to the north-west is an example of a *kanda* and the bright arc-like, almost parallel strips (upper-left to lower-right) indicates the pattern or footprint of retreating river channels used as crop fields in the dry period. The 1984 clip is not available.

3.3.2. Vegetation Cover

As images show, Savar was once a land of *shaal* forest but later this disappeared from most of the *chala* land. However, due to major human intervention, changes have been triggered in the ecology, so that the sequence of vegetation of Savar can be divided into the following phases:

On the basis of Table 3-2, we can classify the major types of perennial vegetation cover. These are: *shaal-baan*, *kathal-bagan*, *bansh-jhars*, and homestead vegetation. These can be identified from space and air borne imagery. But for the specific seasonal crop, we cannot classify these from a single band but we can identify a cropping field suitable for a range of crops. There are four types of seasonal cropping fields, these include: *chala,* *byde, chwak and chars*. The crop chart, given in chapter 6, contains the details of each cropping practice in Savar upazila. Hundreds of crops or crop combinations are possible on certain types of land feature due to high soil fertility, the availability of various HYV crops, good irrigation facilities, and favourable diverse seasons.

Table 3-2: Phases of vegetation cover of Savar *upazila* based on land types

	Land Types	Primary Phase	Secondary Phase	Tertiary Phase
(a)	***Chala***	*Shaal-baan*	*Kathal*, Bamboo Orchards	*Rabi* Crops and Homestead Veg.
(b)	***Kanda***	No vegetation	Grazing Land	Homestead Vegetation
(c)	***Byde***	No vegetation	*Boro* Cultivation	HYV Crops Cultivation
(d)	***Char***	No Vegetation	No vegetation	Jute, groundnut, potatoes etc
(e)	***Chwak***	No vegetation	*Boro* and *Rabi* Cultivation	*Rabi* and HYV Crop Cultivation

Source: Interviewing during fieldwork, 2001 and image interpretations.

To summarise, all vegetation cover is dark in tone but at the margins there is variation. Natural forests have smooth and round margins with filled-polygons; *kathal-bagan* have squared margins with a thinner series of rows and columns while *bansh-jhar* have no gaps inside of squared margins; homestead vegetation has irregular not sharp outer fringes and thicker poly-lines with bright spots in the interior.

(a) Shaal-baan or Shorea Robusta Forest

Interpretation Techniques: The shape of the feature in Figure 3-7 is comprised of irregular polygons close to each other and the relative area depends on the *chala* size. In the dry season the area is surrounded by agricultural fields while in the wet season it is engulfed by water. The pattern of the byde is dissected and the tone is the darkest part of the image and its texture is very smooth. The site is basically on the Pleistocene terrace and not on any of the floodplain area. The feature is highly associated with bydes and no other features are visible inside it; until the 1960s the area was covered by the *shaal* forest but this has disappeared since the 1970s. The forest area was vulnerable to human interference. Now the area is covered by bare soil as seen in the figure. Most of the sensors show the same pattern. Here, the most important parameters are tone and association.

Background and Reconstructing the Past: The images in Figure 3-7 are a part of Bhomka *mauza* in Savar upazila. The evidence shows that the area was a deep *shaal-baan* and, in the late 1960s, it was cleared by the local villagers due to a total loss of control of the then forestry department. After that, until late 1980s, the *khas* land (the govermnent land) was occupied by the surrounding villagers, then it was finally taken back again permanently under government control for use as a training ground for military purposes. In addition to the above discussion, Figure 3-8 shows the gradual decrease of *shaal-baan*, which now remains only on a small *chala*. The north-west block is under PATC and the rest area is developed as grazing land for farm animals.

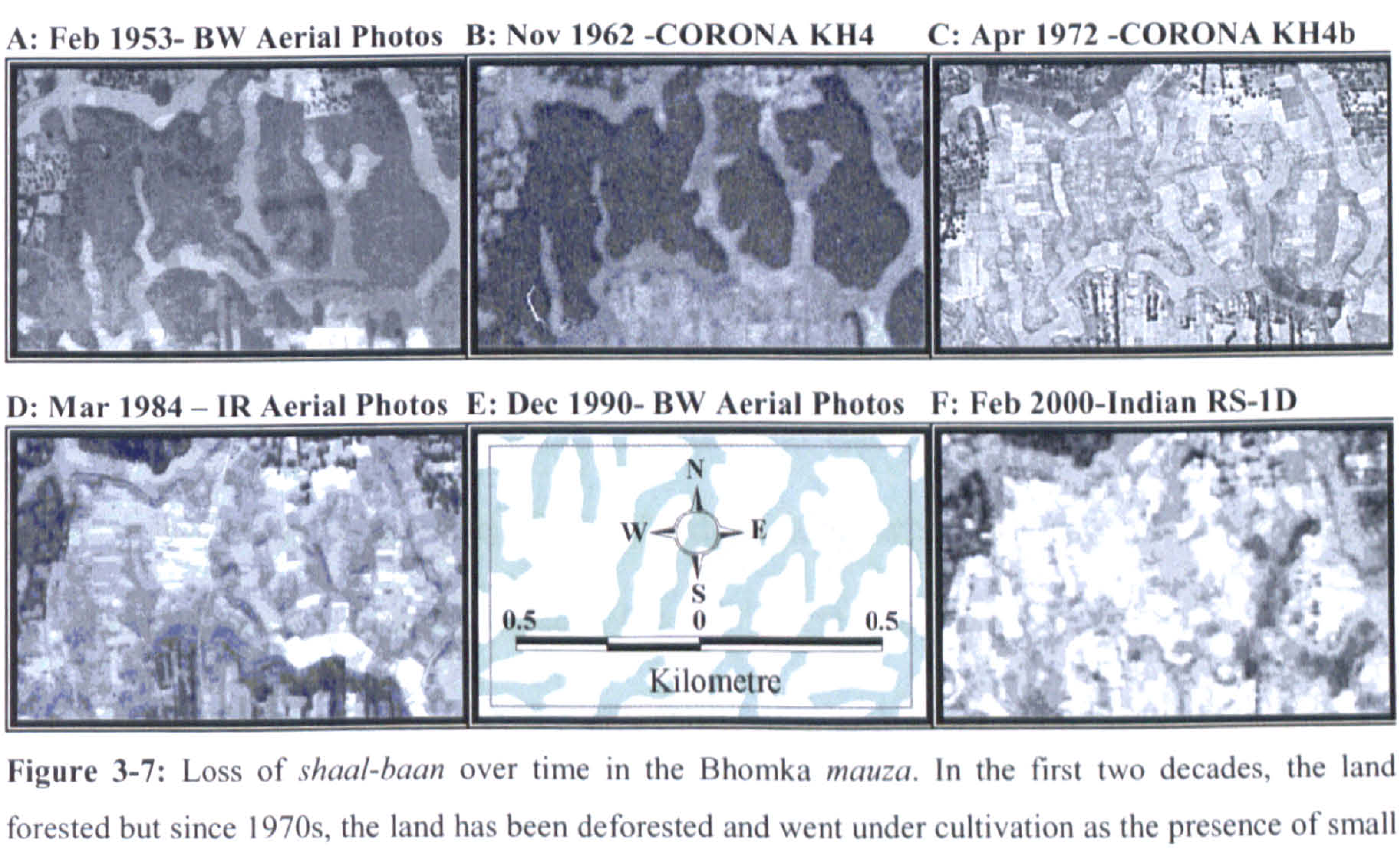


Figure 3-7: Loss of *shaal-baan* over time in the Bhomka *mauza*. In the first two decades, the land forested but since 1970s, the land has been deforested and went under cultivation as the presence of small plots show. In 2000, there was no land boundary at all, because the area was reacquired by the government and used as a military training ground for solders accompanied by heavy artillery and tanks. As a result, the soil of the areas has been exposed seriously and plot boundaries are now demolished. The 1990 clip is not available.

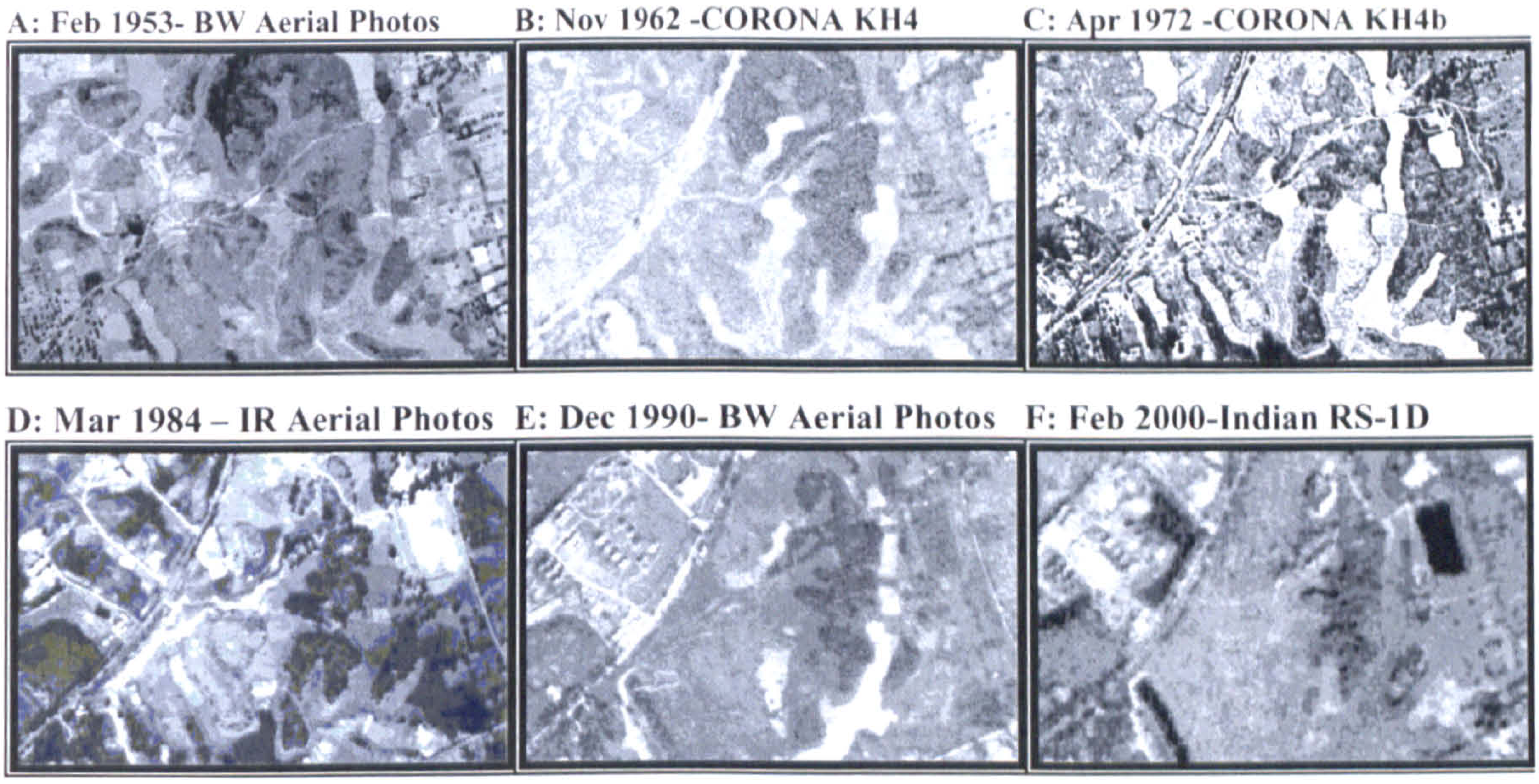


Figure 3-8: The frames of Chhalia *mauza* demonstrate the gradual decline of *shaal* forest which now remains only on a small *chala*. Three newly created ponds have a dark smooth tone. In the northwest, a Public Administration Training Centre (PATC) has been established around the national highway. The bydes have been heavily affected by this modernisation work. The eastern *kathal-bagans* have also vanished.

(b) Kathal-bagan or Jackfruit Orchards

Interpretation Techniques: Jackfruit orchards are very common in Savar. They have a series of rows and columns and cover *chala* land and are extended to *bydes*. The rows and columns have created grids with a dark tone and the outer orchard shape is related to the shape of the *chala*. In fact the *orchards* are highly correlated with the boundaries of plots. *Kathals* are used as fences of plots and each of the smaller grids is also a primary indication of plot size. The orchards contrast with their background. Due to a lack of moisture and organic contents, the soil is bright. In contrast, the leaves of *kathal* are big with a large canopy and enriched with chlorophyll, so overall orchards appear as very dark tones.

Background and Reconstructing the Past: Jackfruit orchards have faced three sorts of consequences. For some the orchard extent has been gradually decreased or in places completely lost. For others the extent has been increased, and a third group is more or less stable with some added additional homestead forests due to settlement expansion.

Figure 3-3 shows a stable situation, while Figure 3-9 shows an increase and Figure 3-10 a decrease of orchard extent. The disappearance of *shaal* and orchards is very interesting. The *shaal* forest disappeared suddenly but jackfruit orchards decline gradually. This was because *shaal* was under government custody as a *khas* land and the orchards were always treated as private property and therefore *kathal-bagan* was under close supervision.

The most important issue about the deforestation in Savar is a *'kathalisation'* (creation of orchards of 'jackfruit trees' or '*kathal*'). Why are the jackfruit trees so significant to the local people? Why was *kathalisation* popular at the cost of *shaal* forest? The answers are very important as most of the *chala* landmass and its ecology was affected by its expansion.

- First of all, the national fruit of Bangladesh is jackfruit due to its significance in so many ways;
- The *kathal* fruits appear in the hungry period of a year when no crops are in the field. A few years back, before irrigation started, the higher dry land was not suitable for any other crop while *kathal* was proved;
- A single tree can produce fruits for more than half a century, and hundreds of *kathal* are produced by a tree in one season;
- *Kathal* is the biggest fruit available in Bangladesh with many cells (known as *ko'a*). The average weight of a fully-grown fruit is about 10-20 kg;
- A ripened *kathal* can be used as an alternative food for an entire poor family as a lunch or dinner and the price of *kathal* is attractive in the local market;
- The katcha kathal could be cooked as vegetable. Some local cakes are made of *kathal*. Seeds of kathal can be stored for several months after being dried in the sunlight. People use it as an alternative to wheat or cook it as a curry. *Kathal* is rich in essential vitamins and minerals;

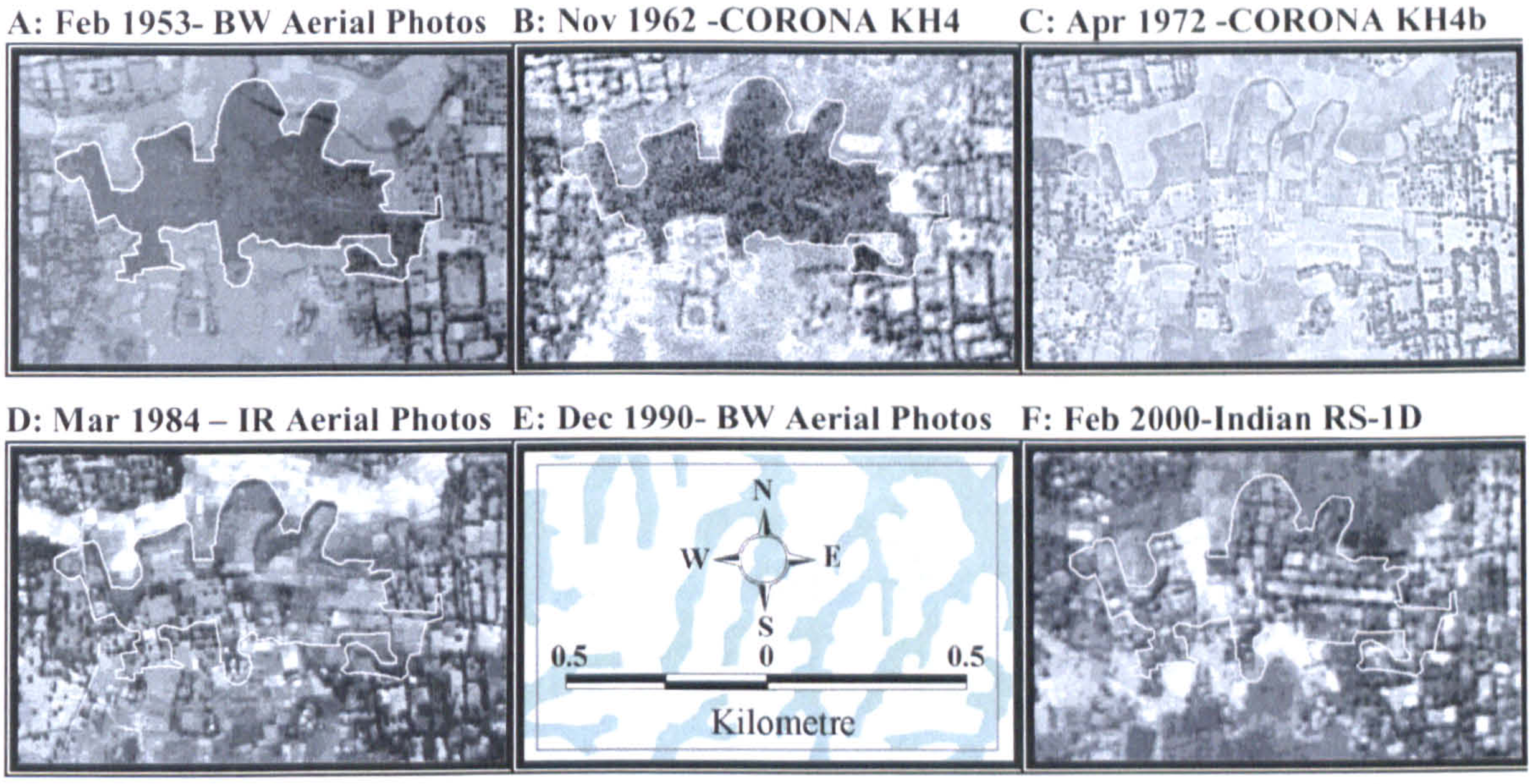


Figure 3-9: Khagan *mauza* is witness to a complete transition from *shaal* to *kathal* and from *kathal's* early to mature stages. This unique example has been captured from the sky. It required about four decades. In the meantime, deorchardisation has started due to the massive population growth in nearby areas. In brief, a natural irregular shape with dark tone in 1950s is surrounded by row and column strips of trees, the first threat of *kathal* to the remaining shaal forest. In the 1960s, with the deforestation of shaal, *kathal* orchards continued their incursion and invasion. In the 1970s, the *shaal-baan* was finally defeated and 10 years later the *kathalisation* had started and it reached a mature stage in 2000. Mature gridirons are the primary indication of human colonisers as inhabitants. The *kathal* trees are clearly visible as the tone of background soils is relatively brighter because of its lack of any moisture content in dry season. *Kathal* is associated with the small *paras* around the edges of *chalas*. **Note:** for all clips, a thin line polygon has been drawn to aid identification. The 1990 clip is not available.

- *Kathal* timber is also valuable. During the economic hardship, farmers sell the timber. A good quality of wooden furniture and frames or casing of a house can be made from it;
- The leaves and new shoots are used as a good food for the farmer's livestock, particularly when the nearby grazing land goes under water for a prolonged period;
- The shadow of a big kathal canopy keeps the house cool in the hot and sunny days;
- In Bangladesh, the land is very much fragmented, and jackfruit trees are used to fence the plot or as a landmark;
- As firewood, dried kathal branches and timbers are excellent;
- During cash crisis, farmers offer a lease on their kathal fruits to a local rich person for a year before starting of the fruit season, the donor enjoys the fruits as interest against the given loan;

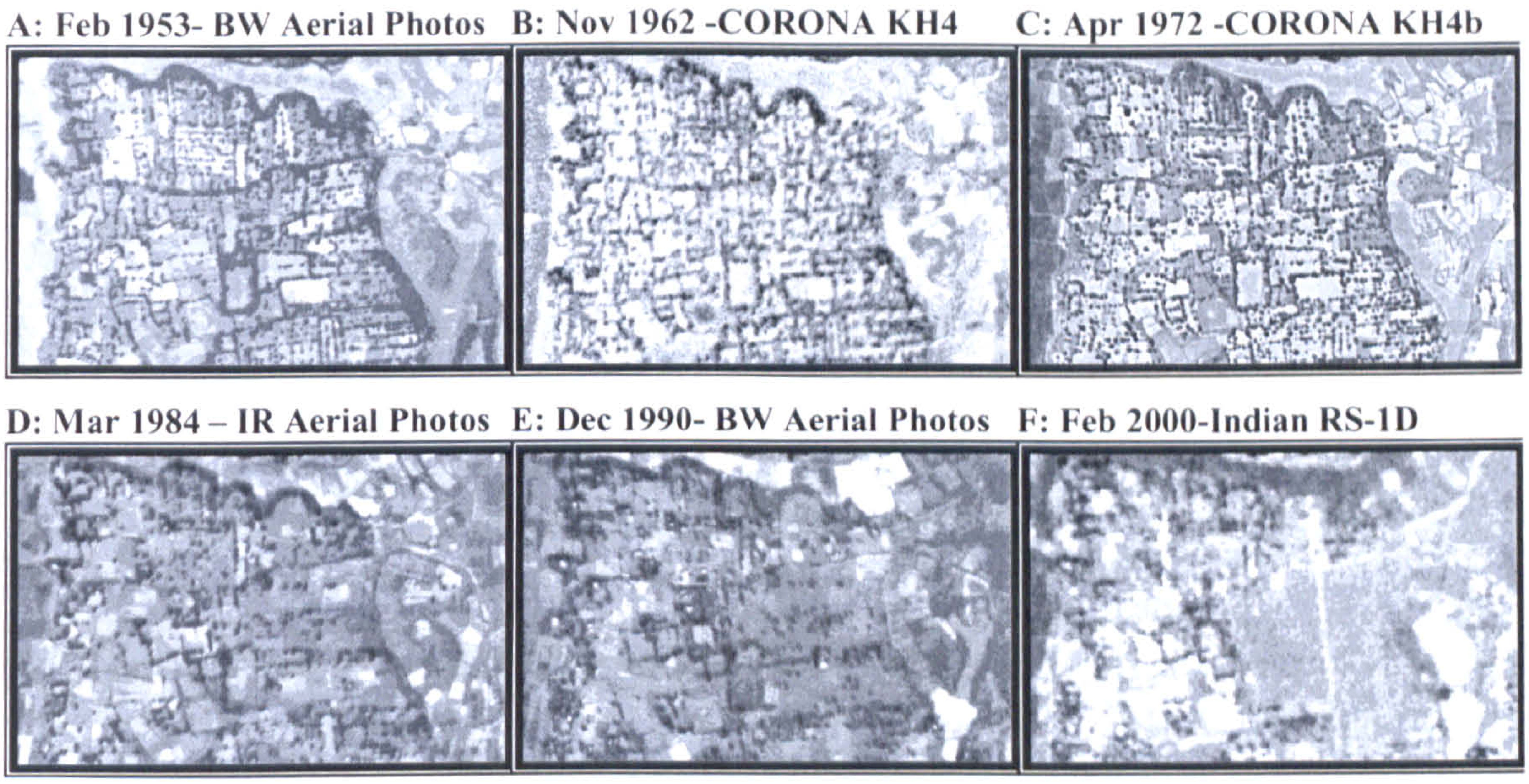


Figure 3-10: In Jamsing *mauza*, *kathalisation* has started decreasing over the last few decades. Until early 1970s, the *kathalisation* in this area was stable and edges of the orchard were villages. A linear and continuous row of trees indicates the underlying footpath and two bright box shapes with a relatively wide dark tone margins indicates ponds with settlements in the early decades. But the early 1980s show the *dekathalisation*. The fifty percent of kathal trees have vanished, including two landmark ponds. In 2000, the situation is drastic, in the east all kathal trees are lost and the *byde* and *chala* have been merged by a private land developer for a building a housing complex and a north-south road layout is visible. Due to the starting of urban expansion, the same situation is visible all around Savar.

- Finally, *kathal* orchards help to identify any high land or a flood-free land. The presence of a *kathal* tree guarantees that the area is flood-free as it cannot tolerate flood or standing water; therefore from the space it is very easy to locate to highland areas.

Due to these advantages over *shaal* trees, *kathalisation* was inevitable. And from all over Savar upazila, the *shaal* forest has been lost forever, along with its enriched ecosystems. But recently, after the start of urbanisation, the '*kathal* economy' is less attractive and same process will take place as happened to the Shaal forest a few decades back, but it will be gradual.

(c) Bansh-jhars or Bamboo-Bushes

Interpretation Techniques: The shape of the above feature is related to the plot size and shape. That is why, in most cases, the edges of the bamboos are straight lines as local people planted them on their own square-shaped agri-plots. *Bansh-jhars* are highly associated with human settlements, so that the people can protect it from theft. Bamboo is suitable for dry land and that means on *chala* lands bamboos are available. The feature also shows similar patterns to nearby plot boundaries. *Bansh-jhar* is not likely to be confused with *shaal-baan*. The tone is very similar to *shaal* forest with no gaps but the texture of *bansh-jhar* cover is relatively rough and coarse. In 1950, there were few *bansh-jhars*, but since then their area has more than doubled.

Background and Reconstructing the Past: As shown on the 1953 photo of Figure 3-11, only one small area was forested with bamboos. But in the 1960s it disappeared. In Bangladesh, bamboos are used for the construction of houses (e.g. wall and roof) and in the modern history bamboos have been used or scaffolding to construct *pucca* buildings. Savar is the main source of bamboos for the adjacent capital Dhaka. So farmers consider it as a cash crop during any crisis season, as it is valuable but they can also make their own houses with it. The northeast part of Savar is famous locally for its *bansh-jhar* (Bamboo forest). The forested area has started increasing, as it is visible on the remotely sensed images. The main reason for that is that local people have got alternative sources of income from jobs in the nearby Export Processing Zone (EPZ), so they no longer consider it important. The other reason is that, due to the establishment of the EPZ, the price of the land has increased dramatically over a decade. Previously it was not suitable for crop cultivation. But now it is highly suitable for urban expansion. If a farmer sells a piece of bare-land, he can survive for a year. So they no longer need the bamboos as a last resort. Figure 3-12 shows the disappearance of *bansh-jhar* in Aukpara *mauza*. This *jhar* was the biggest at that time.

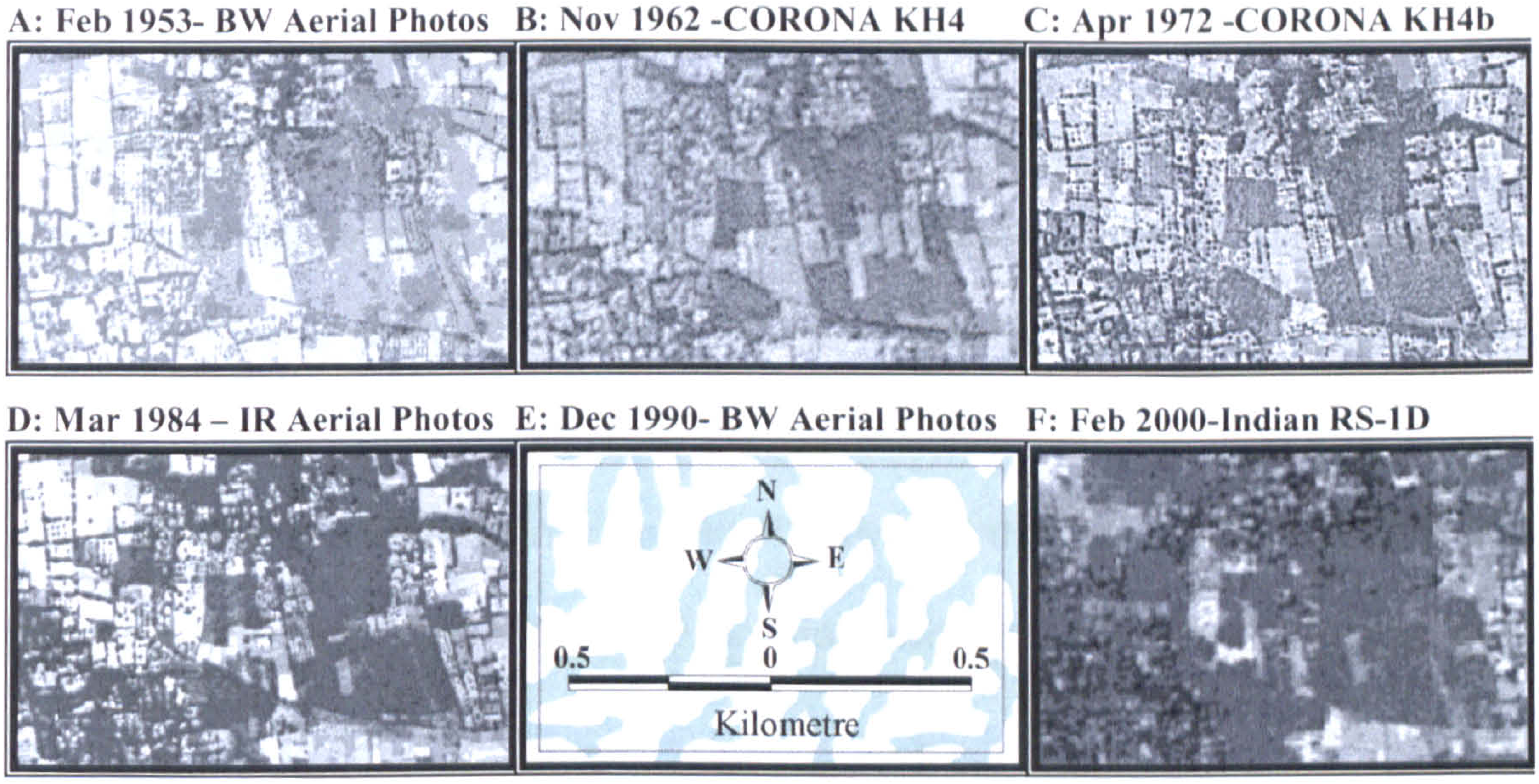


Figure 3-11: In Bara Rangamatia *mauza*, the extent of *bansh-jhars* (Bamboo Forest) are rapidly increasing and gaining popularity in this region. It is recognised by the local people as a cash crop and helps in their times of crisis. The establishment of the EPZ has created an alternative source of income and higher land values, so the farmers no longer sell the bamboo which has resulted in an immense growth of *bans-jhars*. The 1990 clip is not available.

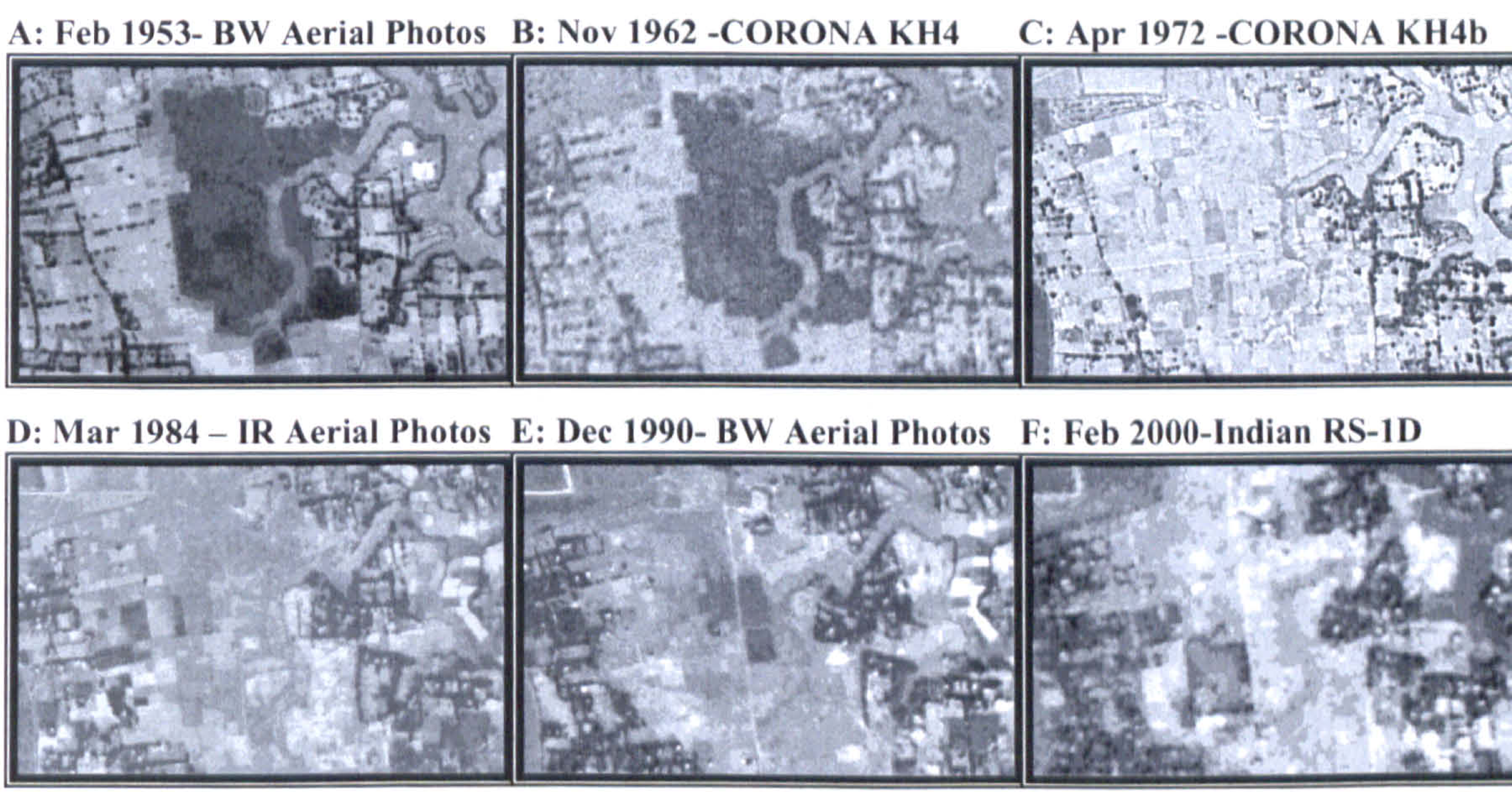


Figure 3-12: The Aukpara *bansh-jhar* area disappeared 40 years ago and is now it is used by *basti* (slum huts). The *bans-jhar* was a remarkable example during the 1950s and 1960s. Later it completely disappeared from the area, because it was on government khas land. The slowly but steadily approaching villages now engulf the surrounding area. Slum people occupy the vacant area. They were recently forced out of the capital city under a controversial rehabilitation project for the beautification of nearby Dhaka at the cost of Savar's interests.

(d) Ghash-khila or Grazing Land

Interpretation Techniques: Figure 3-13 shows the chronological development of a *ghash-khila* from its 1950s land cover. In clip A- *kathal-bagan, bydes*, and *shaal* forest were visible, as we already know how to identify them. A bright tone of a straight road was added in the 1960s as a signal of change. A number of plots of grazing land or *ghash-khila* with their boundaries have been drawn but the underlying legacies of land types are still clear. Both features are superimposed here. Since the 1980s, the land types have gradually lost weight and farming plots have started showing their dominance. The most significant technique to identify the *ghas-khila* are: its sharp and long margins like boxes, very smooth and medium grey tone, a level surface, a number of cattle byres/shades with the brightest tone, and a variation of moisture content according to land type. This is the most extensive farmland that can be seen from the sky. The size of each farm plot is much larger than that of traditional land plots in Savar upazila.

Background and Reconstructing the Past: Due to favourable land features in Savar, the *chala* land is suitable for grazing livestock. But there was no confined and planned grazing land in Bangladesh until the early 1960s. With the help of German assistance, the then government decided to develop a dairy farm in Savar. This dairy farm was the first large scale investment and the Government located the institution in Savar and made a large land acquisition. The current Public Administration Training Centre (PATC), Jahangirnagar University, the Youth Training Centre, the Live Stock and Fisheries research and training centres, the radio station, a military camp and other major government landmark institutions are now on land which was originally under the Savar Dairy Farm's jurisdiction.

In Bangladesh, traditionally, the agricultural plot size is very small and highly fragmented (sometimes less than a few hundred square metres, but in the case of this dairy farm the average size of the plot is the equivalent of those in developed nations like the UK. So it is clearly visible from space. Interestingly the pre-farm images and post farm images still show the legacy of the past land features like *bydes*. But when I visited the land in 2001, these differences were not visible even standing on the concerned plots.

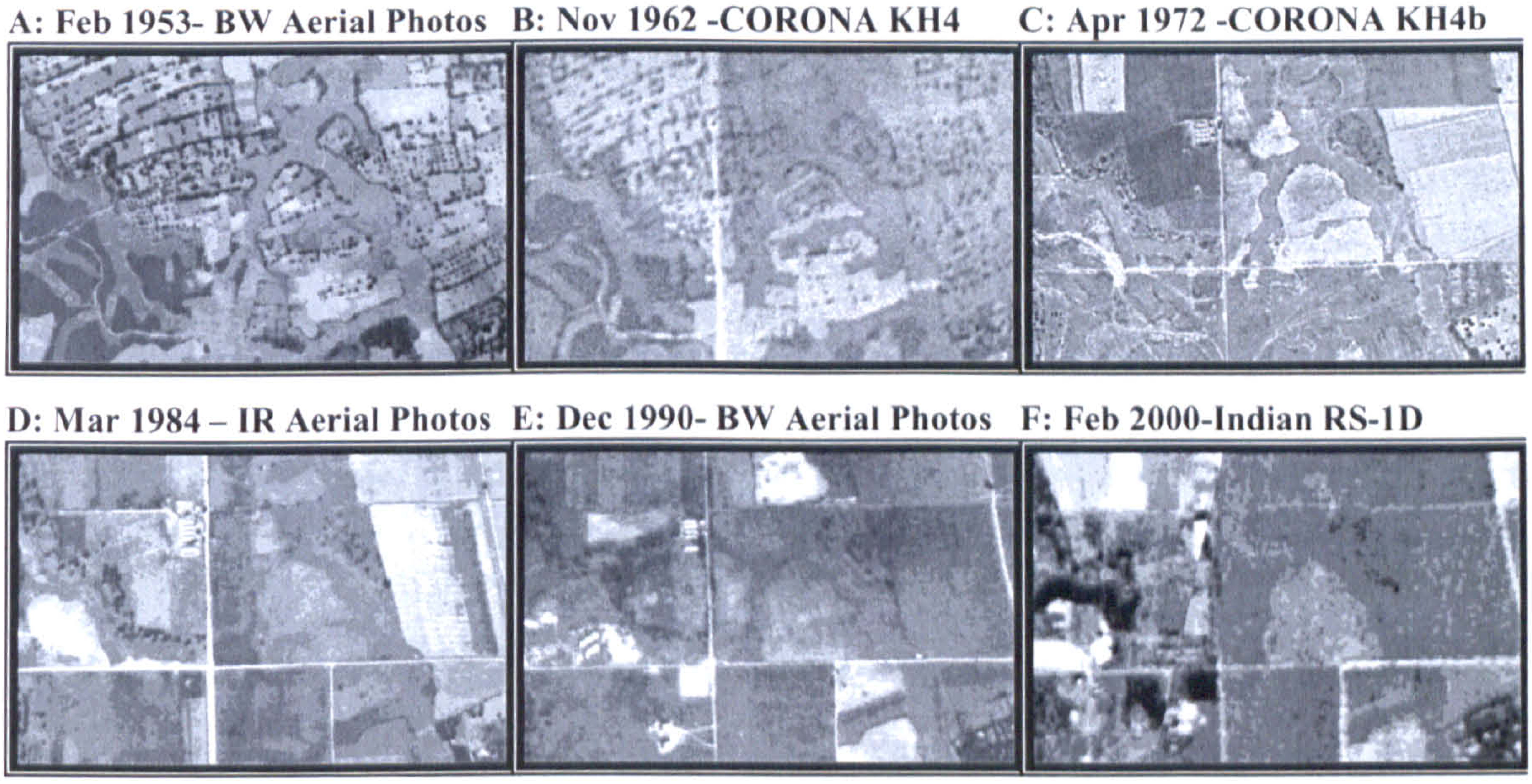


Figure 3-13: The biggest and most modern (Bangladesh Context) Dairy Farm in the country, known as Savar Dairy Farm, is shown partly here. The land is basically used for grazing the cattle-herd and producing HYV Grass and relevant crops suitable for Farming. Clip A of the early 1950s, shows the primitive usage of land, with *shaal* forests and jackfruit orchards on the *chala,* and *boro* rice in the *bydes*. In Clip B, the first footprint of a *katcha* road has appeared. The road was then extended in the 1970s and plots have been clearly marked. Since the 1980s, the farming has been fully operational. In 2000, in the far west we see a few *sarobars* with a very smooth texture and dark tone. Above all, in all images, the background layout of natural *bydes* and *chalas* is still visible with the foreground artificial grids. So the past legacy of the land feature is not removed because the soil moisture holding capacity and temperature still varies within a single block or plot of land.

(e) Fausholi–jomi or Cropping Land

Interpretation techniques: The cropping land or *fausholi-jomi* is spread over the *bydes*, *chwaks* and *chars*. In the dry season these lands are generally occupied by a variety of paddies and *rabi* crops. The identification of land features reflects the identification of crop fields. If a field is not occupied by crops, a relatively clear tone will be visible depending on the land classes. In general *chars* have a much brighter refection compared to *chwak* cropping fields. The common thing for both is that the agricultural-plots are small and box shaped in both cases. Figures 3-3, 3-4, 3-5 and 3-6 are the examples of *chwak, byde* and *char* cropping fields.

(f) Homestead Vegetations or Paalan and Baagan

Interpretation Techniques: Homestead vegetation is identifiable by its very coarse texture with a dark surface, containing bright small dots (reflection of *tiner chaals*). Over the last three decades the utilisation of tin roofs has increased. The vegetation is very integrated and there are no rows and columns like in orchard here. Due to the various land types, the shapes of homestead vegetation covers are varied. But the main associations are the same all over Savar upazila. Before the 1980s, all settlements were near the source of water. So at that time, the coarse textures with a compact concentration of trees around the house were the factor. More than 90 percent of the roof tops until early 1980s was mainly made of straw. In a few cases it was either tiles/tallies or tin. But now, almost 90 percent of the rural houses have tinned roofs. Figures 3-3 and 3-27 are examples of the homestead vegetations in rural and *paurashava* areas.

Background and Reconstructing the Past: It is possible to grow a wide range of trees in the home compounds. They protect the roof from the hot summer by giving shadow, and help to earn money and meet daily household demands for fruit and fuel.

(g) No Vegetation Cover or Exposed Soils

Interpretation Techniques: If there is no vegetation cover, the land is brighter and the texture is relatively smooth with rounded margins. If it is on *chala*, the texture is coarser and consists of boxed small agri-plot shapes if it is on the *chars*.

Background and Reconstructing the Past: Figure 3-14 gives an example of bare soil. In the early decades the land was visible as it was unused, but in later decades, due to heavy use of the land for training purposes, the soils have been heavily exposed. Though both land types contain exposed soils, in recent years the *bydes* cannot be distinguished from space.

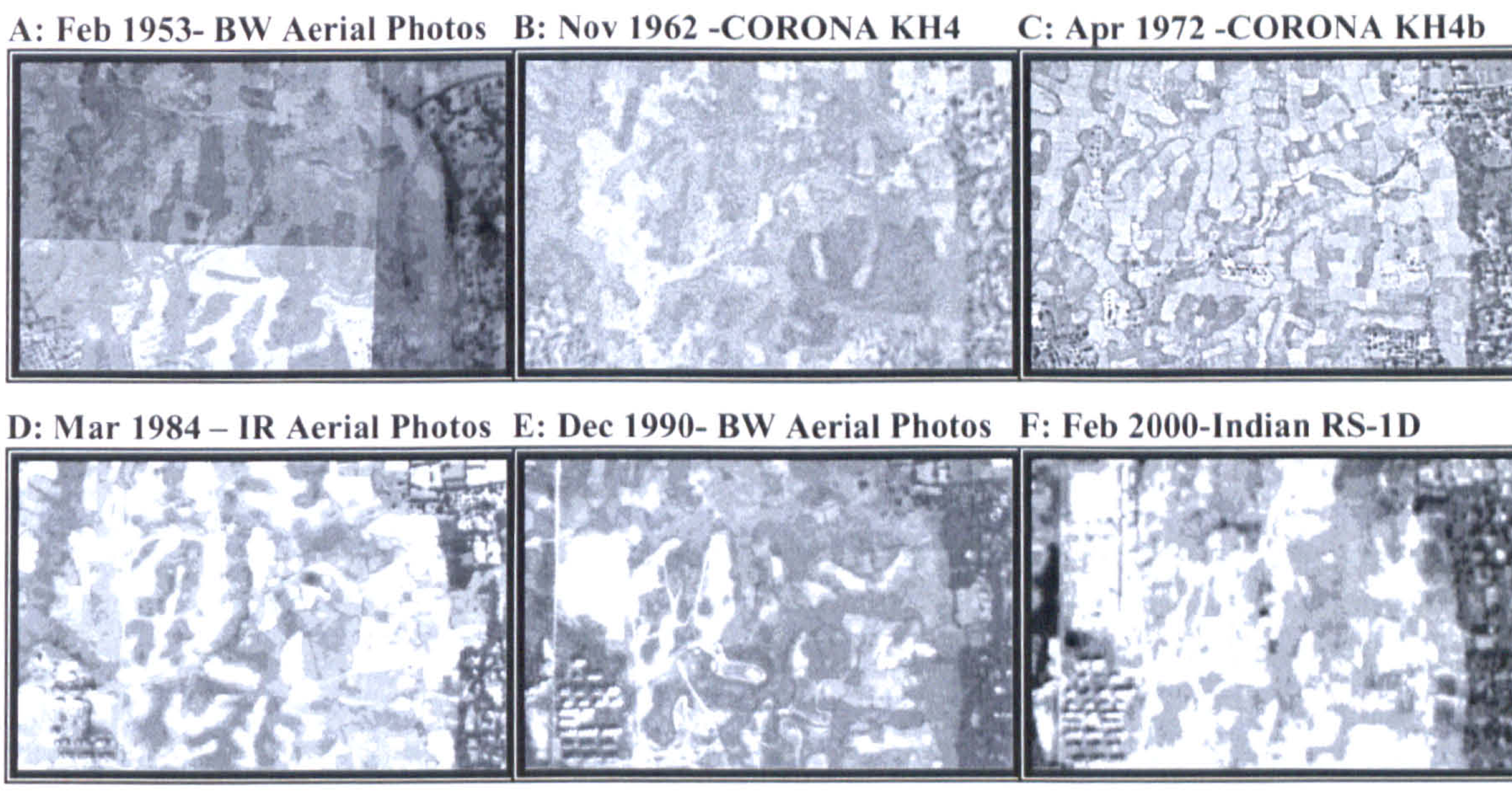


Figure 3-14: The open fields of Kuturia *mauza* were sparsely vegetated in the 1950s and 1960s. Since then there has been no forest cover and no use even for the purpose of agriculture. The *chala* soils of the land are highly exposed and mirror a very bright tone with a little or no moisture content. The nearby village has not expanded, as the area is a restricted government zone.

3.3.3. Road Network

The first footprint of visible roads in Savar was the construction of National Highway through Savar upazila as the Dhaka-Aricha road on a predevelopment society (Figure 3-15); the road has helped to upgrade the status of a neglected part of the region. Savar has become an important part of the national transport network system.

Table 3-3: The road types of Savar and their characteristics

Types	*Example*	*Width*	*Visibility*
Pucca Road	National Highways and feeder roads	4-20 metres	Darker tone with linear shape
Katcha Road	Rural roads and all pre mid-1960s roads.	Up to 4 metres	Brighter tone with linear shape

Source: Surveying during fieldwork, 2001

In general, in Savar roads can be divided into two broad categories: *pucca* roads and *katcha* roads. *Pucca* roads are suitable mainly for motorised traffic movements in all seasons while the *katcha* road is suitable for bicycles, bullock-karts and rickshaw-vans in dry seasons only. *Pucca* roads are carpeted with a bituminised layer on bricks, gravels and sand, whereas *katcha* roads are made of earth-works and exposed soil by levelling and compacting it for the locally-made traditional vehicles. In the wet season *katcha* roads are unsuitable for any traffic and become clay-paths full of wet-reddish-mud. Until the mid-1960s there were no *pucca* roads in Savar upazila. The width of the *pucca* roads varies from 4 metres to 20 metres, but katcha roads are normally a maximum of 4 metres wide. The construction phase of *pucca* roads can be classified as *katcha* roads as visible from the remotely sensed sensors (Table 3-3):

Figure 3-15: A current road network has been plotted on the 1950s traditional land features.

(a) Pucca and Katcha Roads

Interpretation Techniques: The shapes for all roads are, of course, linear. Generally, the *pucca* roads are relatively less sinuous than *katcha* roads. The tone of *katcha* roads is similar to that of exposed soils but, due to its linear shape, it is identifiable. Pucca roads are less clearly visible from space and from the air due its darker materials, but both types of roads are smooth and fine. The *katcha* roads are shorter in comparison to the long and continuous *pucca* roads like national highways. *Pucca* roads are highly associated with big infrastructures whilst *katcha* roads connect villages and local growth centres or bazaars.

As observed, the tone of a roof of any new construction is always brighter in comparison to the older structures. This is also applicable to the case of a road. In addition to that, just before starting the main infrastructure, due to the earth movement, the soils of the entire construction site (which is bigger than the actually planned infrastructure) become highly exposed and show a brighter tone in the images.

Background and Reconstructing the Past: Figure 3-16 shows the sequence of roads at Jahangirnagar Campus. In that figure, in the 1960s, the first imprints of roads in the region become clear. Then roads were made of only earth and not carpeted with bitumen. No trees had been planted and the surrounding surface was not grass covered. In the 1970s, in the north-western section, the soils of building constructions and of roads were a mess. But the eastern national highway (north-southward) was properly managed and became less clear as the vegetation cover and bitumen made it less distinguishable. Though the roads were widened over the time until 2000, the visibility is not so clear. Most of the roads in this area can be seen as sharply as in the 1960s. Due to its elongated linear shape, the footprint of the roads can be guessed easily. In identifying roads, aerial photos and CORONA images were especially good.

(b) Bridges and Culverts on the Rivers

Figure 3-17 shows the Nayarhat bridge. The road was constructed in the 1960s but there were no bridges until one was constructed at Nayarhat in the late 1970s. By the construction of this bridge, the local economy was boosted by the establishment of a business centre and a famous *haat*. Now, Savar is connected by four major bridges with the surrounding regions. These are, Nayarhat bridge in the northwest, Amin-Bazaar bridge (in early 1970s) in the southeast, Ashulia bridge in the northeast (in early 1990s) and Singair bridge in the southwest (in late 1990s). The opening of these has helped to increase weight of Savar upazila rapidly.

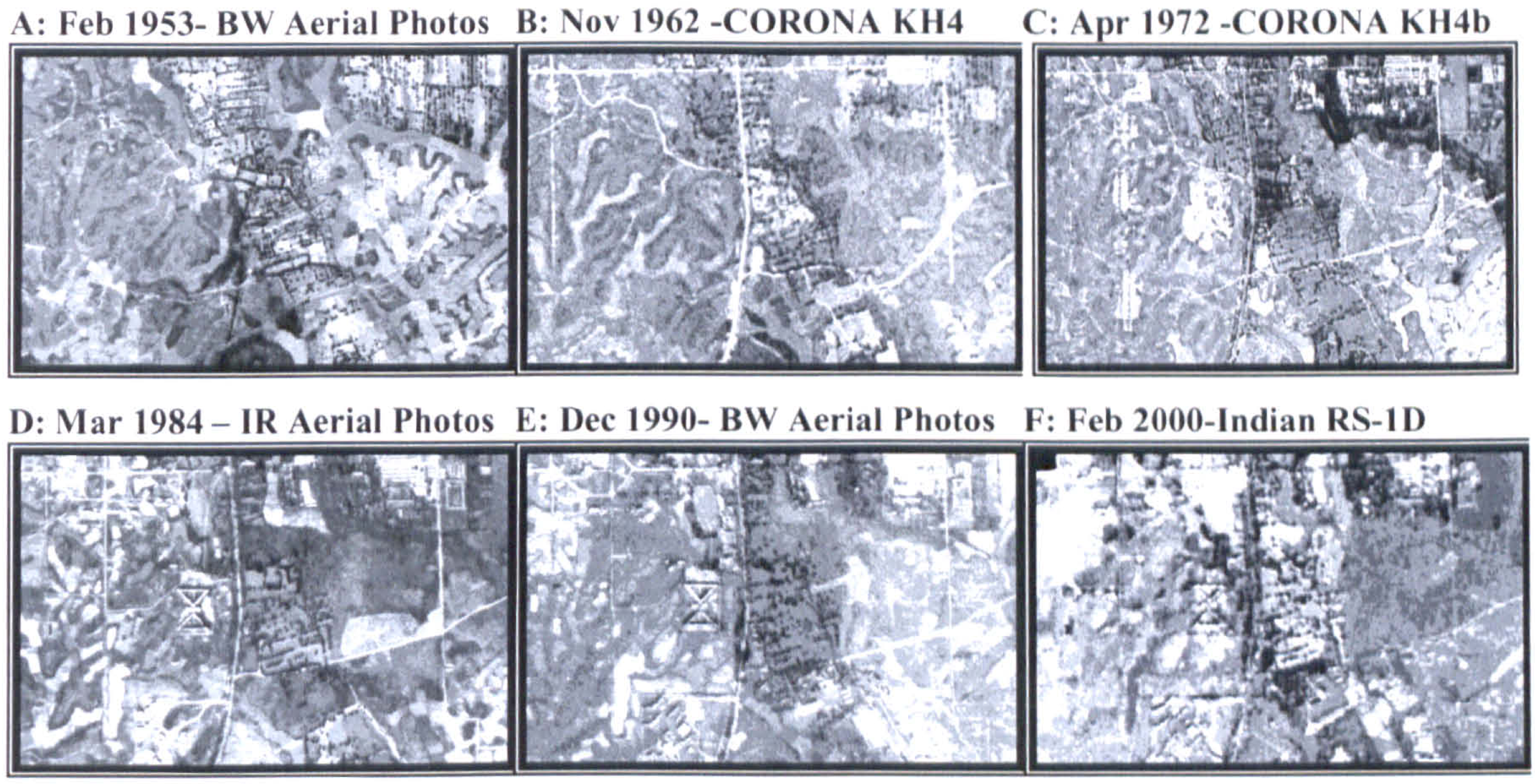


Figure 3-16: The Figure shows the 1950s, when were no roads at all the area. In the 1950s, the early stage of construction of roads is clearly visible. However, the brighter tone faded with metalling and is now less clearly visible. With an increase of infrastructure, the number of small roads has increased. Finally most roads were *pucca* by 2000. With the construction of roads and development work, the once clearly visible *bydes* have also faded.

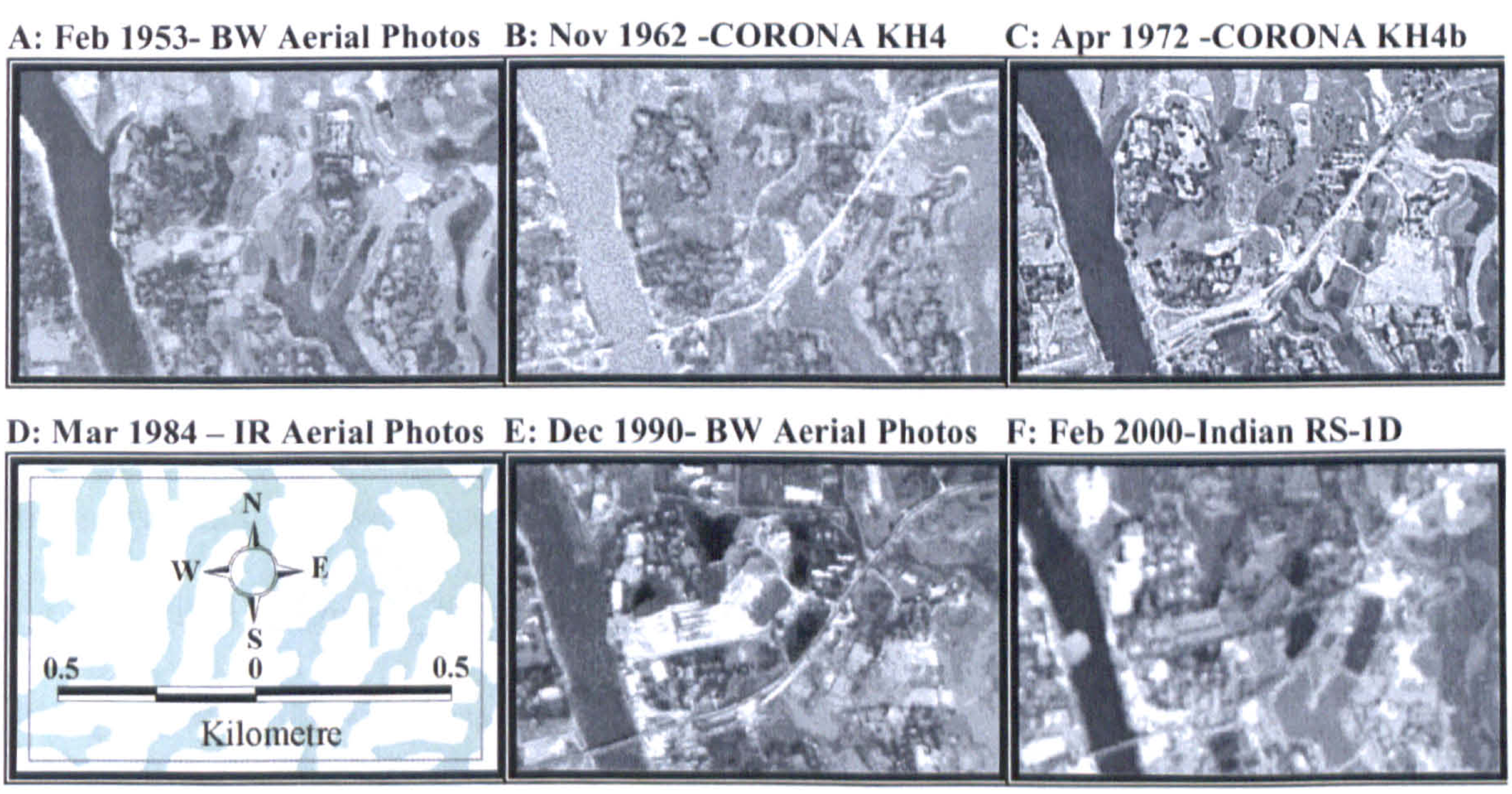


Figure 3-17: Construction of Nayarhat Bridge was a big event in north-western Savar and helped to change the local economy and land use. The sequence was: in 1953 no bridge and no road; in 1960 the road under construction; in 1972 the bridge under construction and completed in 1973. Since mid-1970s, after the construction of bridge, a new economy emerged and the landscape has rapidly changed in decades. The 1984 clip is not available.

3.3.4. Rural Territories

There are three categories of villages in Savar upazila (Table 3-4). These are *Gaon, Dia* and *Kandi.* The *gaon* is surrounded by chala while *dia* and *kandi* are surrounded by *chwaks* and *chars* respectively. *Kandis* and *dias* are both like islands in the flood season but *kandis* are highly vulnerable to river bank shifting due to its unstable sandy base, while dias are very stable and not endangered by the river due to their stable clayey base of *gaarh.*

Table 3-4: Several types of villages in Savar *upazila* and their typical locations

Type	Located	Comments
Gaon	Mainly on *chala* landmass close to *bydes* or *chwaks.*	Expanded to orchards or open land, the *gaon* was primarily a *shaal* forest, then orchards and finally a village.
Dia	Mainly located on *tek* and surrounded by *chwaks*	No place to expand and very stable, generally it is a round shaped island.
Kandi	On *Kanda* land, near to River banks or on *chars*	No place to expand and highly vulnerable to flood erosion, generally it is a linear shaped island

Source: Interviewing during fieldwork, 2001 and image interpretations.

(a) Gaon: Villages on Chala Land

Interpretation Techniques: The village on *chala* land is visible by its homestead vegetation. There is serious lack of smoothness of land cover. The vegetation cover is densely concentrated in comparison to orchards but without following any row and column-like grids. The tone is dark in general with white small spots of the roofs, and the distribution of dwellings is random with a *gaon.* The margin of a *gaon* is very rough but integrated. Figure 3-18 shows a very typical village without any expansion and the intensity within the village is visible.

Background and Reconstructing the Past: A *Gaon* is a traditional village in Savar upazila located on a *chala.* Most of the *gaons* are close to and mainly dependent on *bydes*-based agricultural practices and possess backyard jackfruit trees. In the wet season there is usage of the adjacent *byde* as a water route for the movement of commodities and its inhabitants. Though Figure 3-18 reflects the stable *gaon,* there can be expansion. Some of the *gaons* have variation. The following *gaon* named Gerua (Figure 3-19) is encircled by *bydes* and has no way to expand naturally. This is a very introverted village which has no other option but to expand toward its own centroid, starting from the surrounding *byde* margins.

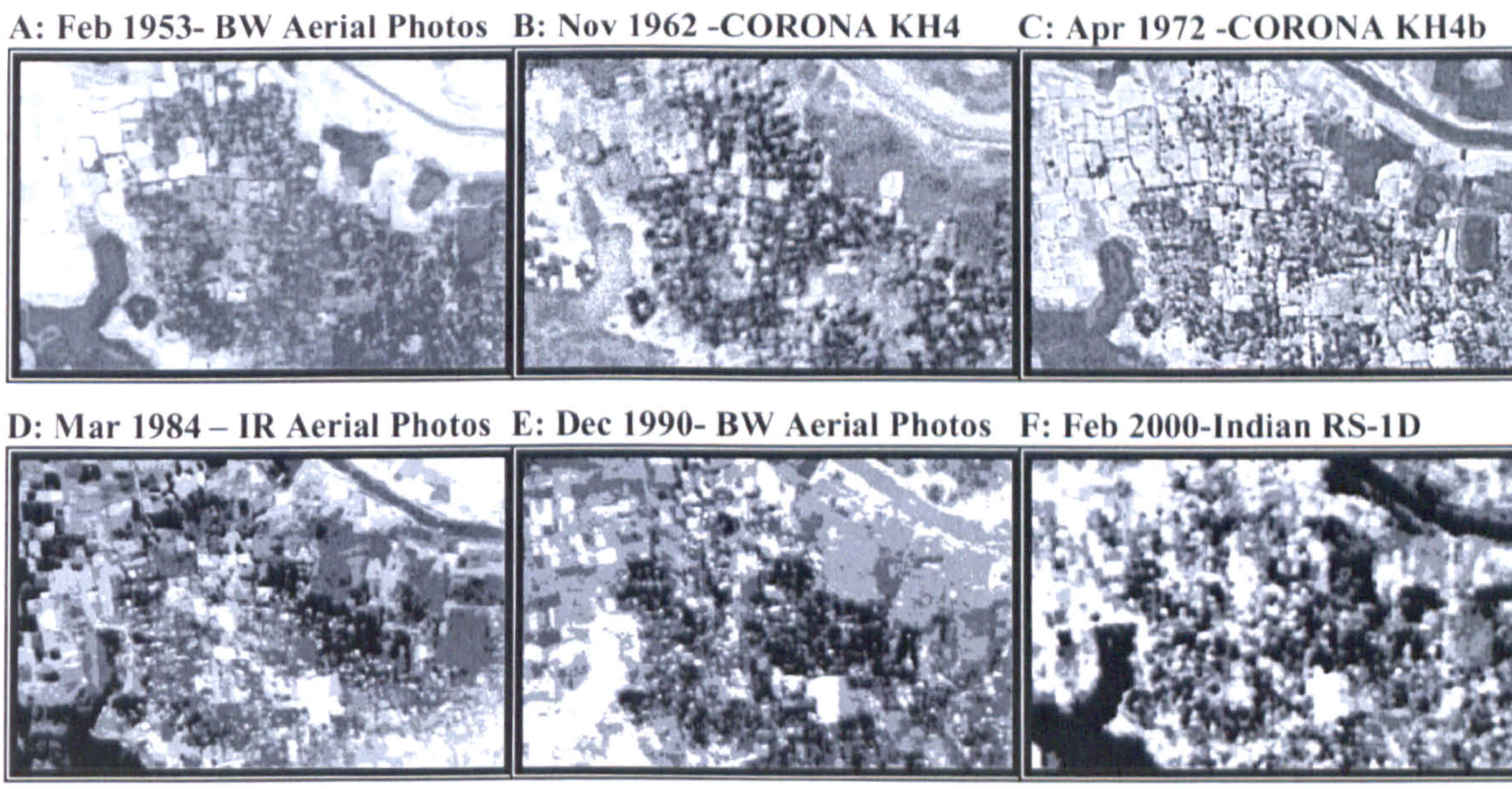


Figure 3-18: Konda *mauza* is a typical example of a *Gaon* on a *chala*. The above village has been very stable over a long time. This *chala* is linked with the southern *bydes* and northern Karanatoli *khal*. There is no road connection with other parts of the upazila. In the dry season, the people use rickshaws or bullock-carts to carry their products or themselves and in the wet season only traditional boats are the mode of transport. The reflectance shows that the village is highly populated from the beginning, because it was an ideal location of a village until the 1970s.

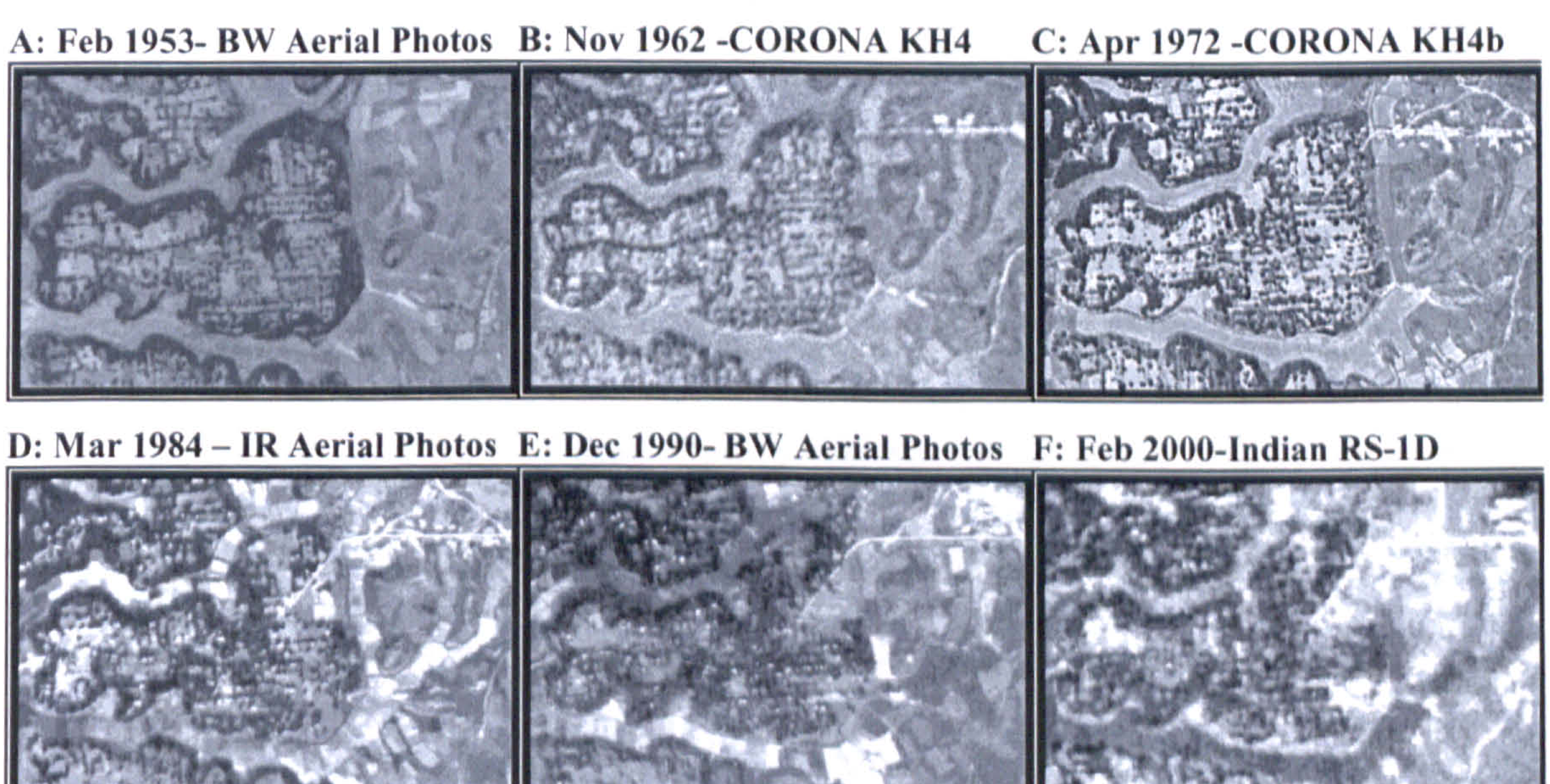


Figure 3-19: Gerua Mauza of Savar upazila is a very stable village

Figure 3-19 shows house compounds and fields in irregular polygons related to the shape of the bydes. All of the edges of the village are dominated by houses, as shown by relatively dark objects continuous in nature. Each house is a part of the dense homestead vegetation including traditional fruit trees and vegetables, and that is why it is significantly different from the specialist orchards located inside the mauza territory. The roofs of the early houses were mainly made of straw and bamboo, so they are not directly visible but since early the 1980s the roofs were mostly replaced by the *tiner chaals* and, as a result, we can see the brighter spots in the homestead compounds in the images. It is also clear that, due to the nearby bydes, the village houses are concentrated there to get the easy access to their fertile agricultural land and in the wet season the inhabitants can use their backyard to anchor their boats easily. However, in recent years the inhabited area has approached closer to the jackfruit orchards. This is a reflection of a reduced dependency on agriculture and water-based communication and a greater dependency on the road network, as seen in the east and on the non-agricultural economic activities. But more or less, the village is a classic example for this region. Figures 3-20, 3-21 and 3-22 illustrate respectively: the relations between orchards and villages; the village has changed due to land acquisition; and gradual joining of cluster paras have made an integrated village.

(b) Dia: Village on Island like Tek

Interpretation Techniques: *Dia* is normally situated on *tek* and detached from the main *chala* land though it is part of that. During wet season, it looks almost like a round shaped island. The *dias* have homestead vegetation with settlements. *Dias* are mostly associated with *chwaks* and relatively bright from the sky.

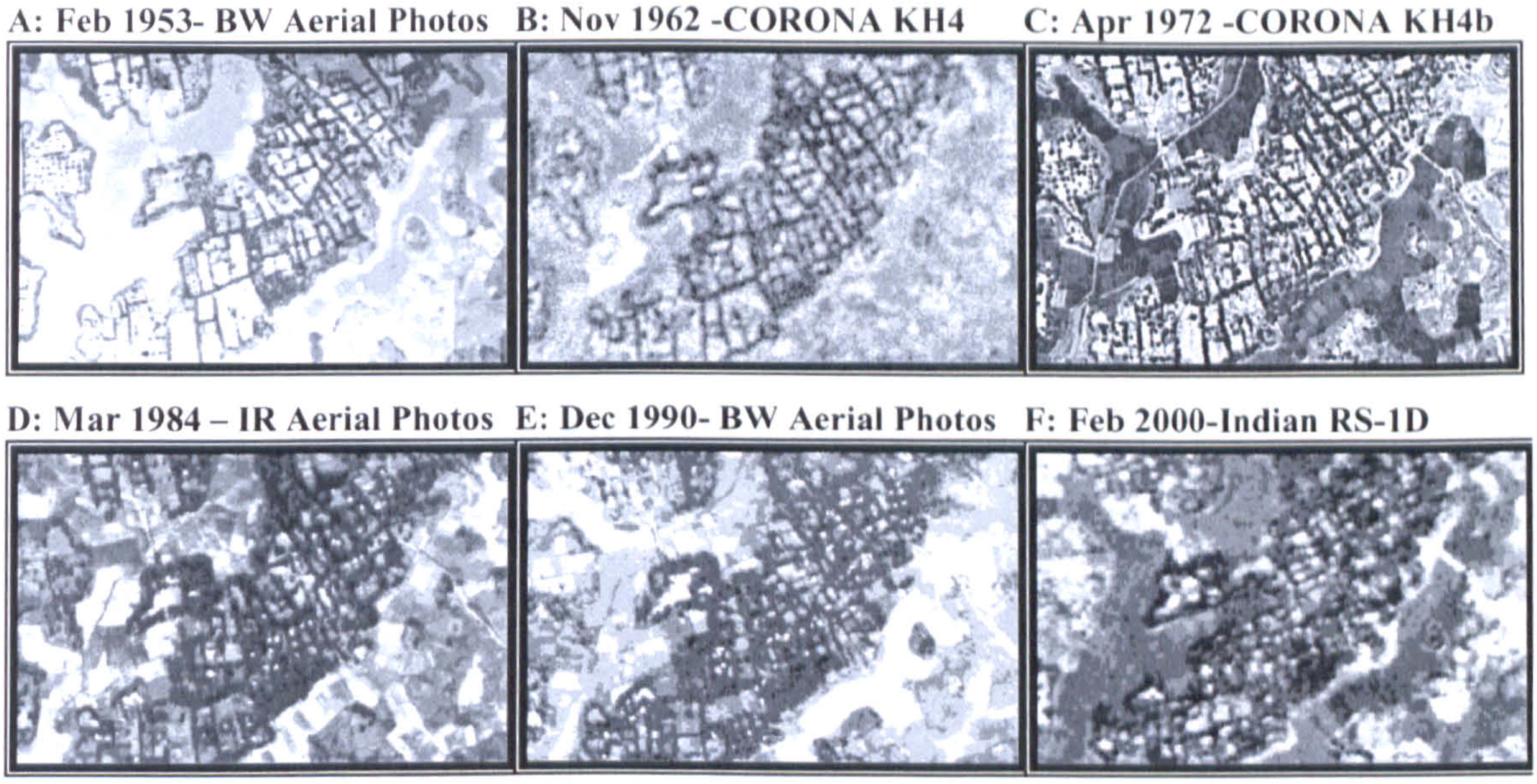


Figure 3-20: Dharanda mauza is as an example of how orchards and settlements can co-exist peacefully. The *kathal-bagan* has been merged with the houses without any loss. The expansion was introverted and did not expand as it is surrounded by very low *bydes*. The numbers of houses and vegetation cover has increased simultaneously.

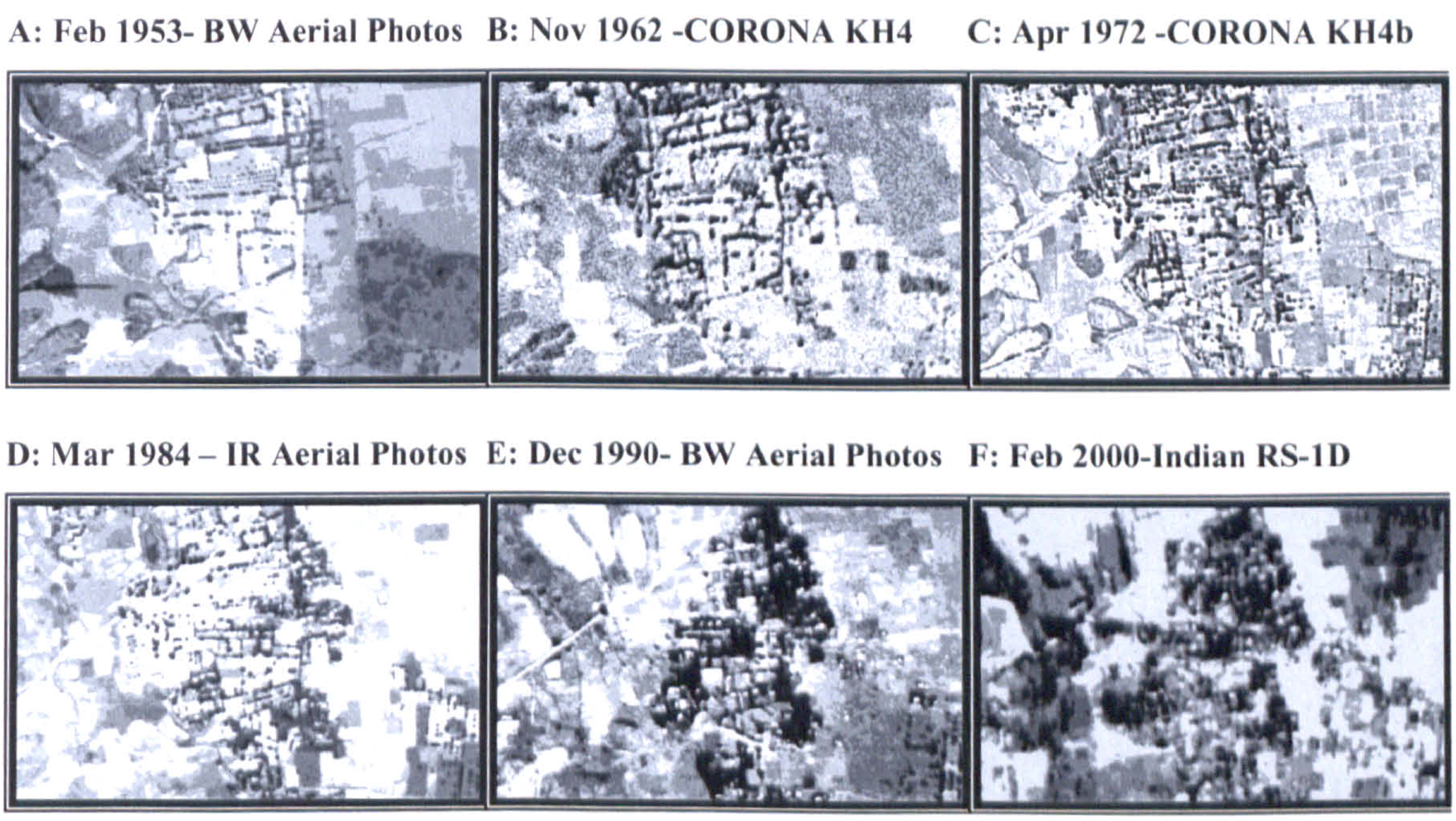


Figure 3-21: Baipail mauza is an example of the retreat of villagers on *chala* land due to land acquisition. In the first three decades the northern side was under the village environment and was expanding naturally but the land acquisition in the 1980s has forced them to move further south.

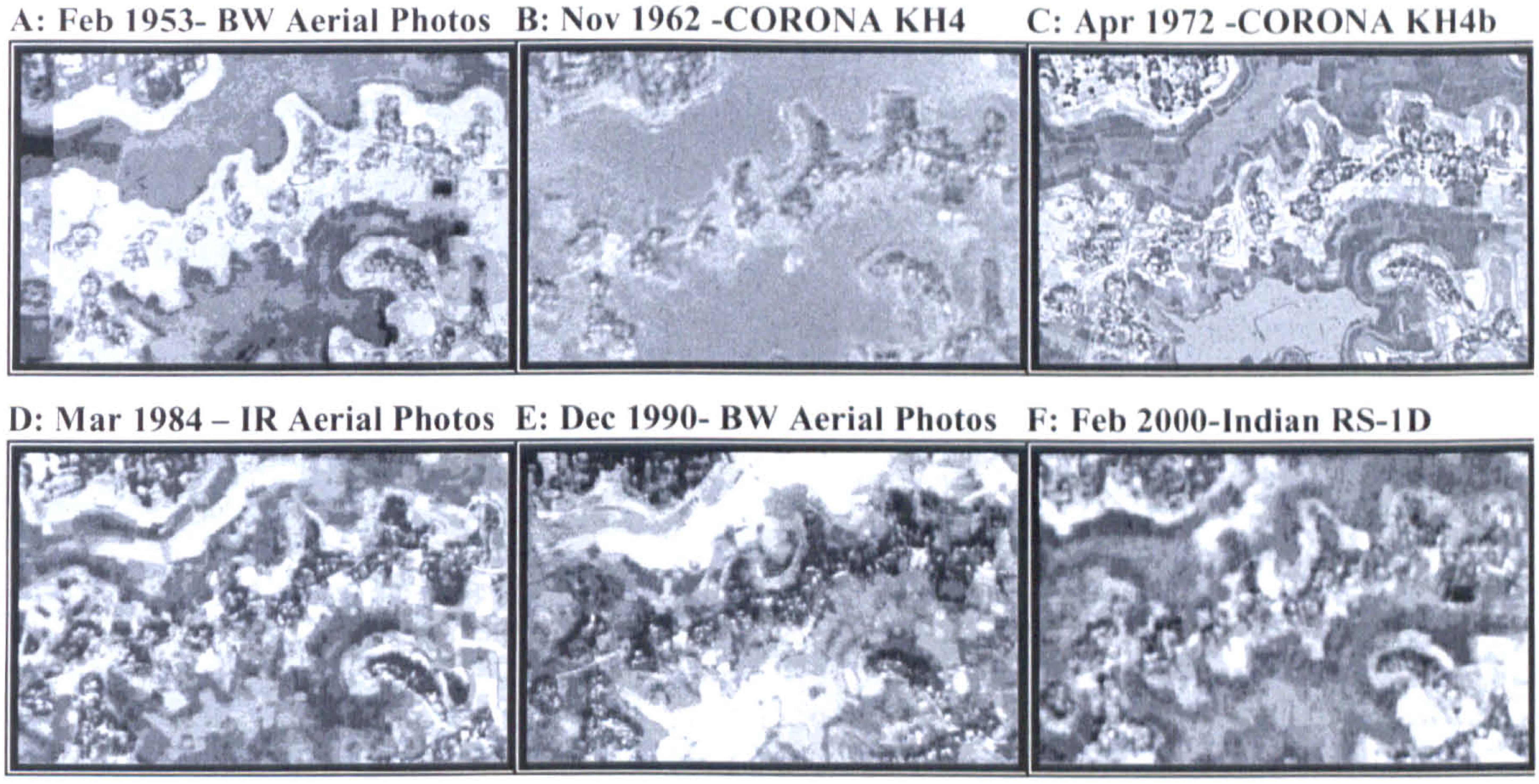


Figure 3-22: Gokulnagar village in the early decades was in cluster (locally known as *para*) or detached form. But with the expansion of the *para*, the clusters are getting closer and in most cases have merged ultimately.

Background and Reconstructing the Past: A *dia* is an isolated village situation of a tek like an island in the wet season. In Figure 3-23, the middle island-like feature is a dia known as Pipulia *mauza*. The villagers use local rickshaw vans in the dry and boats in the wet season for all sorts of communications and transportation. Though the location of *dias* is very close to rivers, these are not vulnerable to river bank erosion because their base is on *chwaks* rather than on *chars*. This is why the people of *dias* are risk-free in comparison to *kandi* villagers.

(c) Kandi: Village on Natural Levées

Interpretation Techniques: The levées are formed by the meandering river. They are linear shaped and vary from a few metres to a few kilometres in length. The *kandi* has homestead forest and the significant number of houses reflect as white and bright spots. Figure 3-24 shows the northward shadow of the *kandas*. The *kandas* are located on *kandi* and surrounded by the *chars* or *naaljomi*.

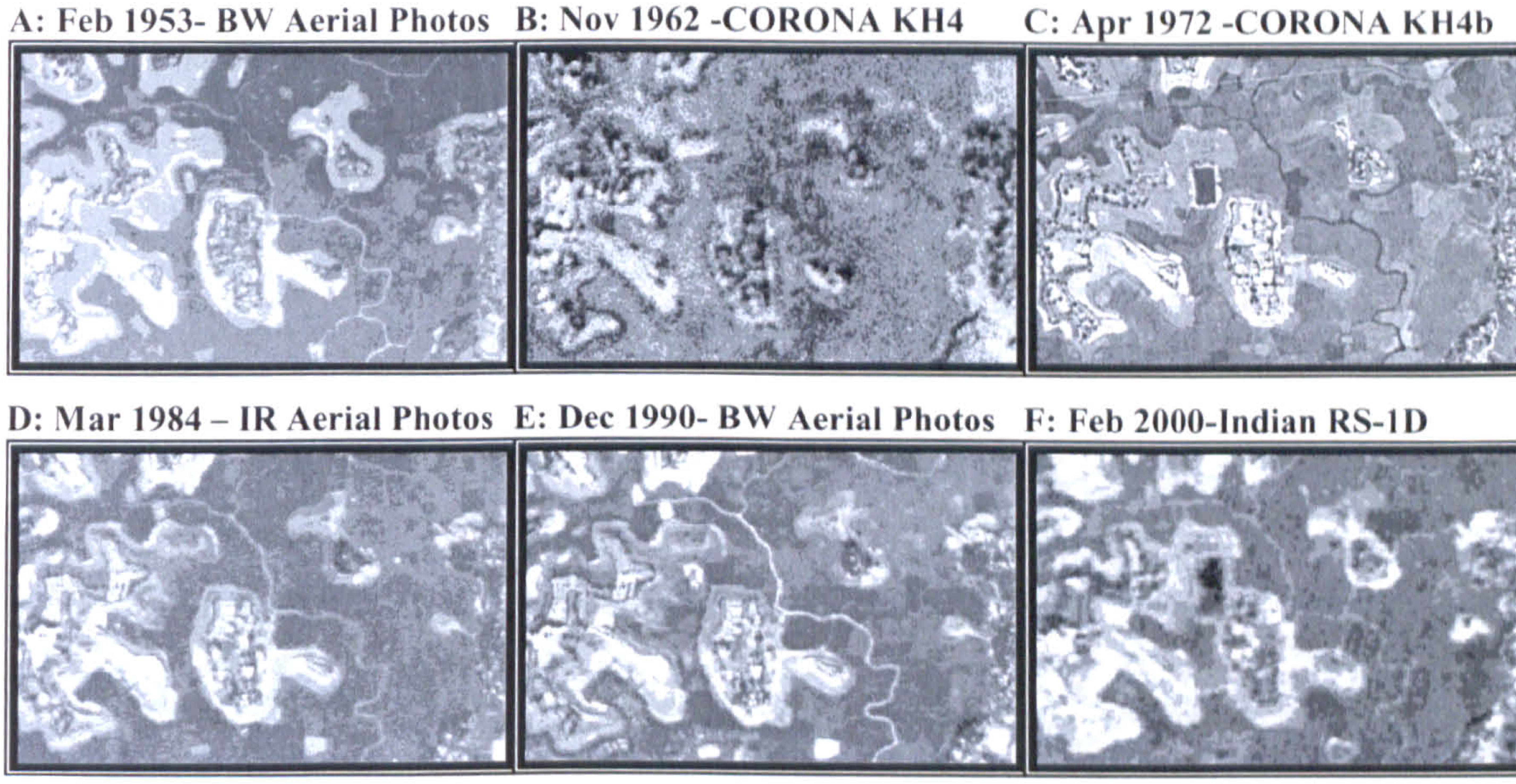


Figure 3-23: Pipulia village is a good instance of *dia* due to its location on *tek* and surrounded by *chwaks*.

Background and Reconstructing the Past: A *kandi* is a village on *kanda* or natural levée. The *kandi* follows the river-created linear patterns with a dark tone that is easily separable from the *chars* or *naaljomi*. A *kandi* has no way to expand its territory, as it is highly vulnerable to floods for several months. Only a few metres wide and more or less a kilometre in length. this is a very compact form of village. The area is not suitable at all for urban expansion. *Kandis* may be drowned the river and may rise again after decades. Figure 3-24 shows stable *kandis* while Figure 3-25 demonstrates defenceless *kandis*.

3.3.5. Pro-urban Developments

In 1972, Savar came under the limelight when the new government of Bangladesh inaugurated the national monument to honour her three million freedom fighters who sacrificed their lives during the nine months war in 1971 against Pakistan. Establishing a monument in Savar was a great event in its history. From then, Savar got special attention and this was first step in developing Savar upazila as a whole, a symbol of its drive to ultimate urbanisation.

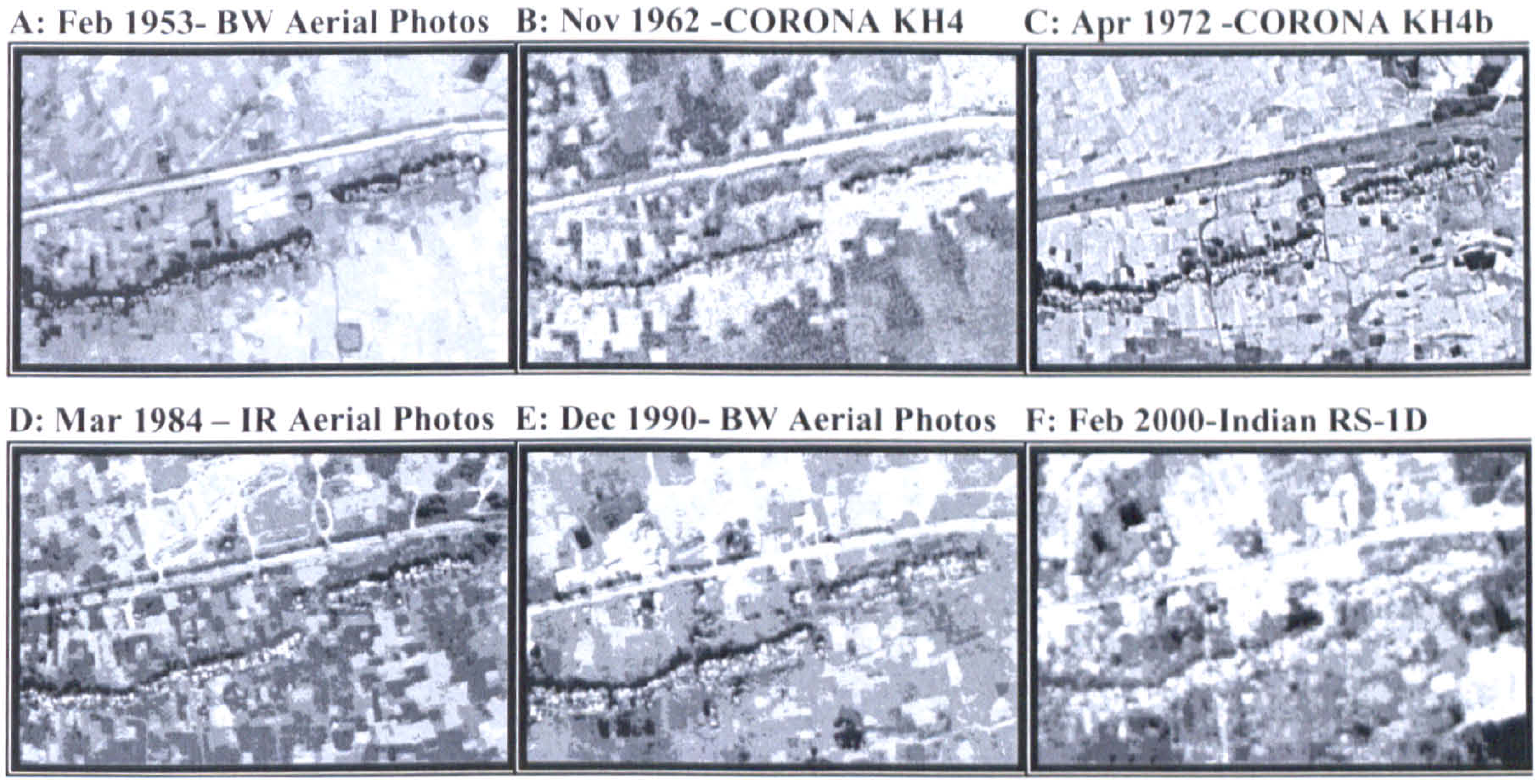


Figure 3-24: Almost linear shaped land features with vegetation cover (here parallel to a road) are locally know as *kandis* of Bilamalia *mauza* on natural levées. If you observe carefully, it is possible to see that all *kandis* have a northward shadow. That means kandi is a higher platform than the surrounding *chars*. Additionally, due to presence of its soaring homestead vegetation, it reflects clear shadows northwards. The white/bright small spots, indicates houses.

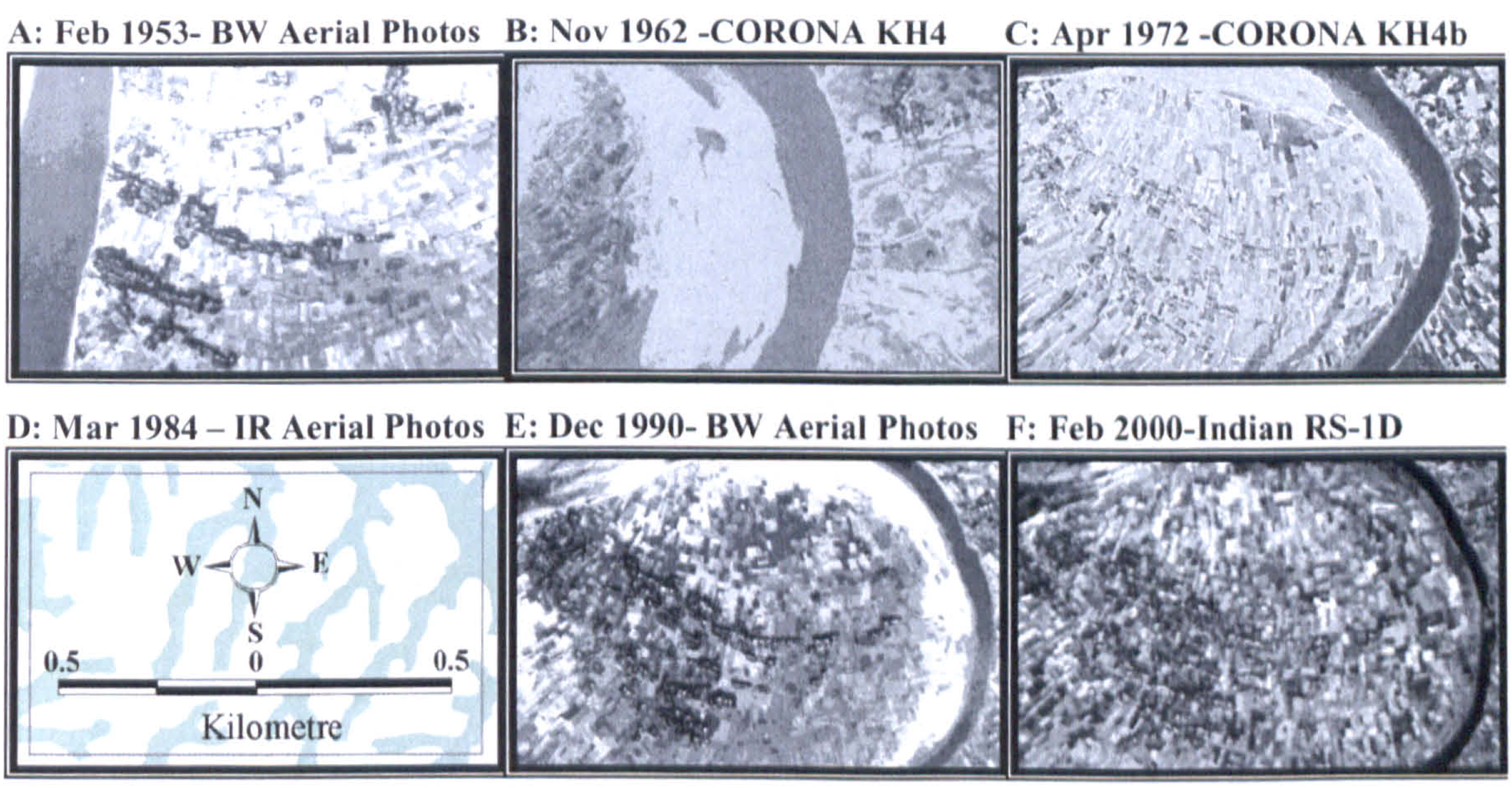


Figure 3-25: These images show a *kandi* may be defenceless. Musurikhola village was fighting with the Dhaleshwari River. It was eroded, destroyed and again rose up from the destructive riverbed. The amount of river water also delcined gradually, which reduced the capacity of devastation. The village has now got full stability. The 1984 clip is not available.

Until the late 1970s there was no modern settlement in Savar upazila. Since then three types of settlements area have arisen: spontaneous (and unplanned) urban settlements under the country's '*paurashava* act' like 'Savar *Paurashava*'; planned urbanisation under the banner of housing societies like 'Bank-town housing society' or 'Ashulia Model Town'; and the government-funded planned towns like 'Senanibas or Jahangirnagar Towns'. Savar *Paurashava* has the biggest population concentration of the upazila but there is no provision of basic urban needs like running water supply for its customers or a roadside electrification programme. However, these three major categories of settlement have housed the mass population surge into the area, mainly from the adjacent and highly saturated Capital Dhaka. A summary of the pro-urban settlements is listed in Table 3-5.

Table 3-5: Types of pro-urban infrastructures in different development context

Type	Examples	Comments
Monument	Jatiya Smritishaudha	National monument of Bangladesh
Paurashava	Savar *Paurashava*	Unplanned or spontaneous
Real Estate	Bank-Town	Planned by the Housing Society members
Autonomous	Senanibas	Planned and funded by the Govt.

Source: Interviewing during fieldwork, 2001 and image interpretations.

(a) Parks and Monuments: Jatiya Smritishaudha

Interpretation Techniques: The brightest feature in the monument is the cover of red ceramic bricks plus concrete and surrounding gardens dominated by soft grasses with a homogeneous fine texture. The reflection of this grass seems darker than the outer monument compound's wild grasses. In the centre of the pentagon shaped park in Figure 3-26, is the 50 metre high monument itself. In general, we can identify any well-maintained parks using its characteristics, which may include some lakes and brick surface covers and the balanced geo-metric intersections.

Background and Reconstructing the Past: From the sky view, the historic national monument is a spectacular and wonderful architectural creation. As evidence shows in the Figure 3-26, in 1990, the monument was completed and its peripheral development was finished. The land was forested in the 1950s and cleared by 1960s while the national highway split its land. In December 1972, the foundation stone of National Monument was laid immediately after the CORONA 1972 image was captured. By 1984, it had a bright tone with a variety of geometric shapes. In 1992, the master plan of the area was being implemented with adjustment of the *bydes* into *shapla-jheel*.

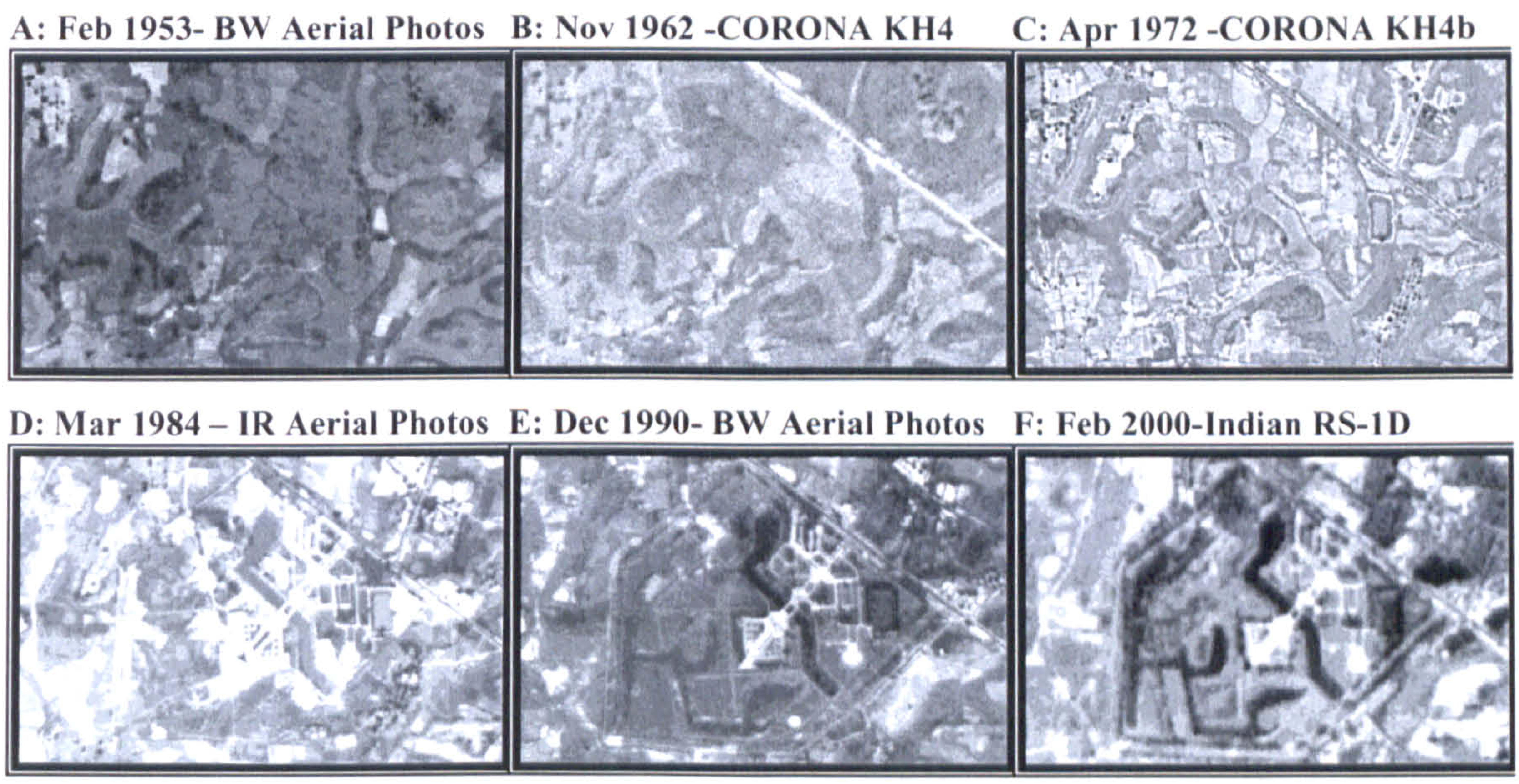


Figure 3-26: The National Monument of Bangladesh near Nabinagar well-known as Jatiya Smritishaudha. This prodigious national symbol of pride has been a focus for Savar as a whole. Its beautiful portrait also reflects from the sky. The bright centre is the monument itself and the dark features are the sharp edge *shapla-jheels*. The smooth grey part is the well-maintained park of the compound.

(b) Savar Paurashava: Unplanned Settlement Expansion

Interpretation Techniques: Figure 3-27 is a part *paurashava* in Savar upazila. In clips A to C, the area looks like a village in the west and an agricultural field in the east. The small box-shaped agricultural plot boundaries are also visible clearly. But in the early 1980s, a number of bright objects are visible, which are *pucca bari,* and their concentration increased rapidly by 2000. In the village, homestead vegetation and crops are dominant and the houses are not focused properly but in the rural settlements the houses are prominent, with little or no vegetation. The tone fluctuates here. The interesting thing is that the village is also gradually merged with the urbanisation. There is no road network visible as the area is very unplanned and congested. In the northeast since 1970s, a garden centre or nursery is visible with a dark tone.

Background and Reconstructing the Past: This village was declared a paurashava in the mid 1990s after a massive boom of settlement in a few years. A paurashava is a local municipal authority with a very limited amount or resources and power. The reason for the attraction is the presence of the Dhaka-Aricha highway in the east. A connecting road (near the northern margin, east-west) between the national highly and a *bazaar* located in the northwest. All of the upazila headquarter offices are here or very close by. The land was relatively cheaper and has a good road communication with Dhaka.

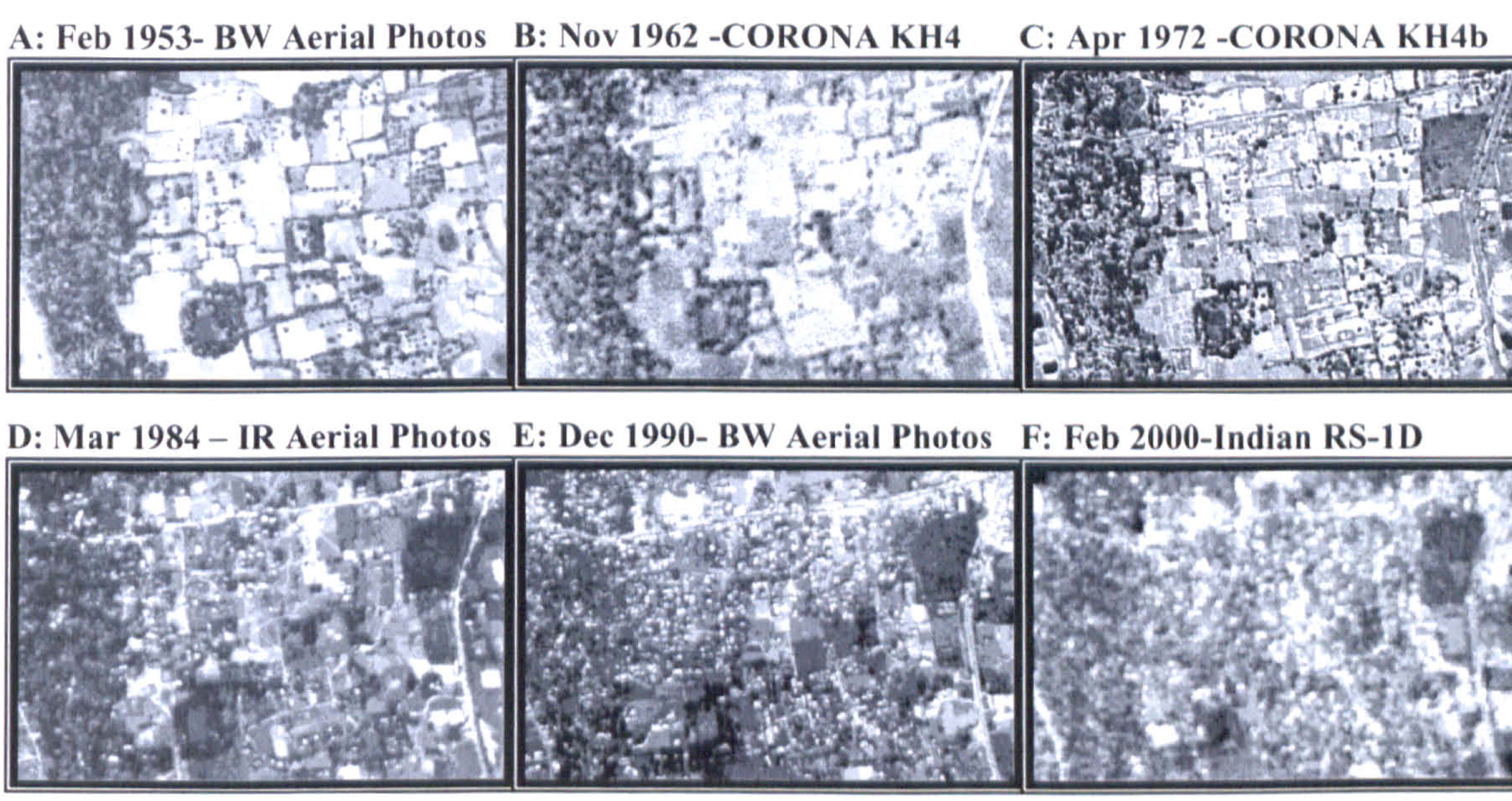


Figure 3-27: Ward-2 of Savar *Paurashava* shows a dramatic increase of unplanned settlements on previously agricultural land as the plot boundaries show. This populated medium highland still suffers seriously from a peak flood almost once in every five years. The brightest dots are the individual houses. How the western villages have merged with the rest is also visible.

(c) Planned Town: Senanibas

Interpretation Techniques: In the 1950s, as the darker tone shows in Figure 3-28, the area was under thin *shaal* forest cover. Apart from footpaths, no other human feature is seen at that time. The southwest linear bright feature is a road and the first intervention and construction in the B sequence. In C, for the first time, the shallow bydes are exposed more clearly. The black spots show a few houses and the linear bright object indicates a bullock-cart road, in the mid-south and north-west respectively. In the 1980s, the southwest part shows such brighter reflectance as major construction work was going on. Later, in the E and F images, this area becomes relatively less and less bright while the other corners are under the process of construction as bright exposed soils indicate. In the centre point of E and F, a square dark object (bright in D frame), indicates a pond. Three more ponds were also dug here, as images indicate in 1990 and 2000. However, one small bright object in the mid-south is a 5 storied residential building, as an example. The northward shadow indicates its height. The town is highly dissected by roads and a sufficient number of *pucca* roads are an associated feature of a planned town.

Background and Reconstructing the Past: Figure 3-28 is the most changed landscape in the region. The frames indicate the central part of the town in this area. The reason for providing this example is to see how a planned city grows. There is no other town in Savar upazila which can give the same detailed sequence.

In the 1950s the area was mostly covered by *shaal* forest. In the 1960s the forest was mostly cleared after the construction of the National Highway (in the SW Corner) and in the 1970s the underlying soils and bydes are completely exposed due to the absence of any vegetation cover. In the 1980s the main development work of the town was going on. In the 1990s the development work was finished in the south-western part. By 2000, the area had been expanded to the eastward and more construction was going on.

(d) Housing Project: Bank Town

Interpretation Techniques: Figure 3-29 is a medium highland and used for agricultural practices since mid 1980s. The most common phenomenon for any housing project is having no trees or orchards. The following housing society is in between

Karnapara and Karanatoli khals. There is a gridded road network, which is connected with the national highway. The tones of the pucca buildings are like the brightest objects and have similarity with others. The background is smooth due to a thin grass cover over the surface. There is a distinct difference to the remaining agricultural fields. In the northwest the relatively big bright boxes indicate the private unplanned industries associated with the highway and *khal* which have made the settlers' lives difficult. Housing in the settlement has grown with the help of private initiatives.

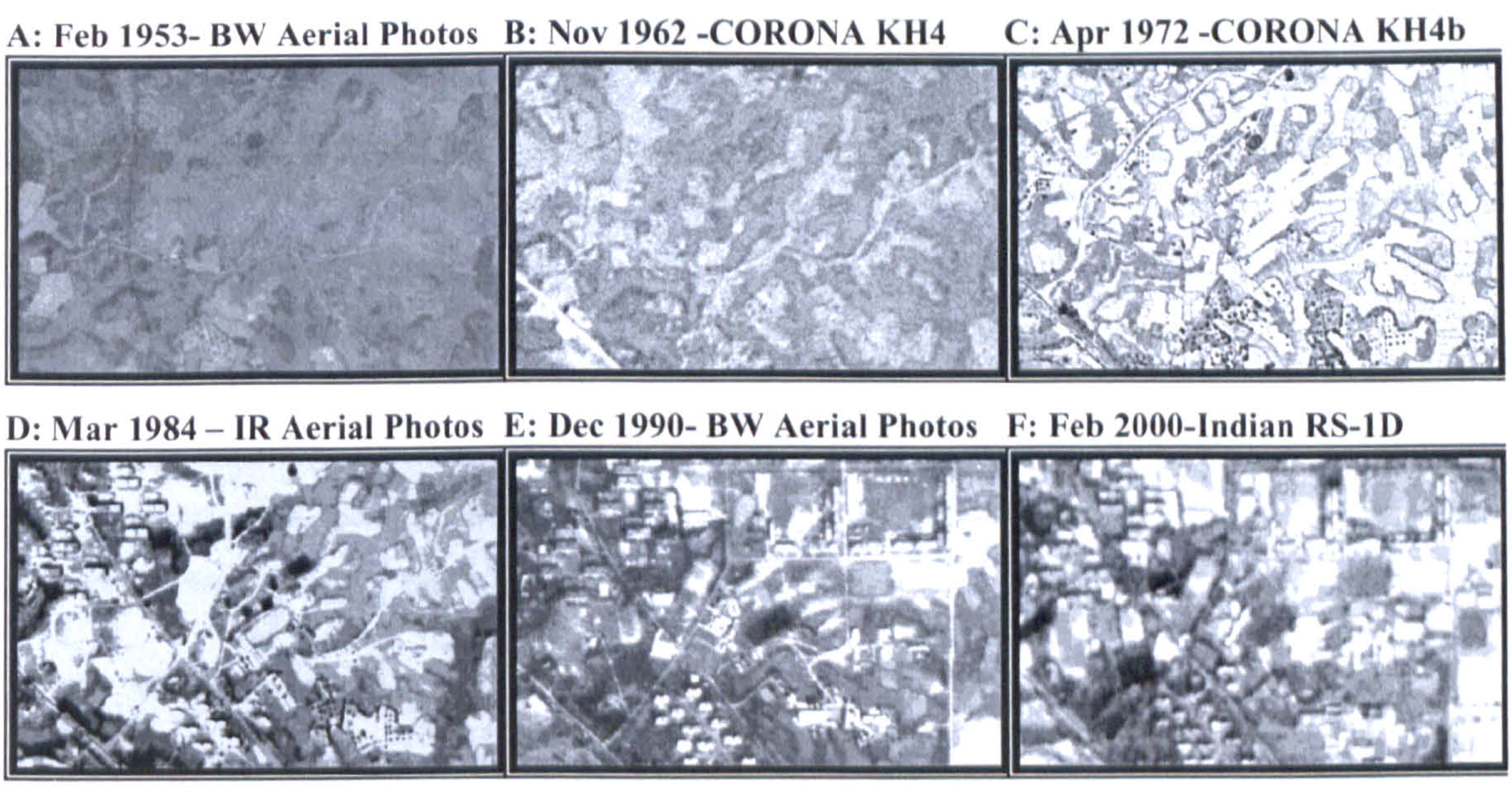


Figure 3-28: The gradual development of a government funded planned town from a sparse *shaal* forest is revealed in Tattibari *Mauza*. The roofs of the structures were bright when they were new and they became grey or relatively darker when older. This restricted town has modern urban facilities.

Background and Reconstructing the Past: After the commissioning of any housing society in the private sectors, all traces of the former land use disappear if it was orchard. If not, it is very hard to see any trees on that land. The reason is the small size of plots (5 to 8 decimal of land). The society or real estate authority provides all the necessary utility services and the housing societies are an important factor in the urbanisation process. Though Savar has hundreds of housing projects, only a few are in the construction phase. Bank-town housing is one of them (Figure 3-29) but here the northern *khal* possesses a high concentration of black polluted water with a very bad smell.

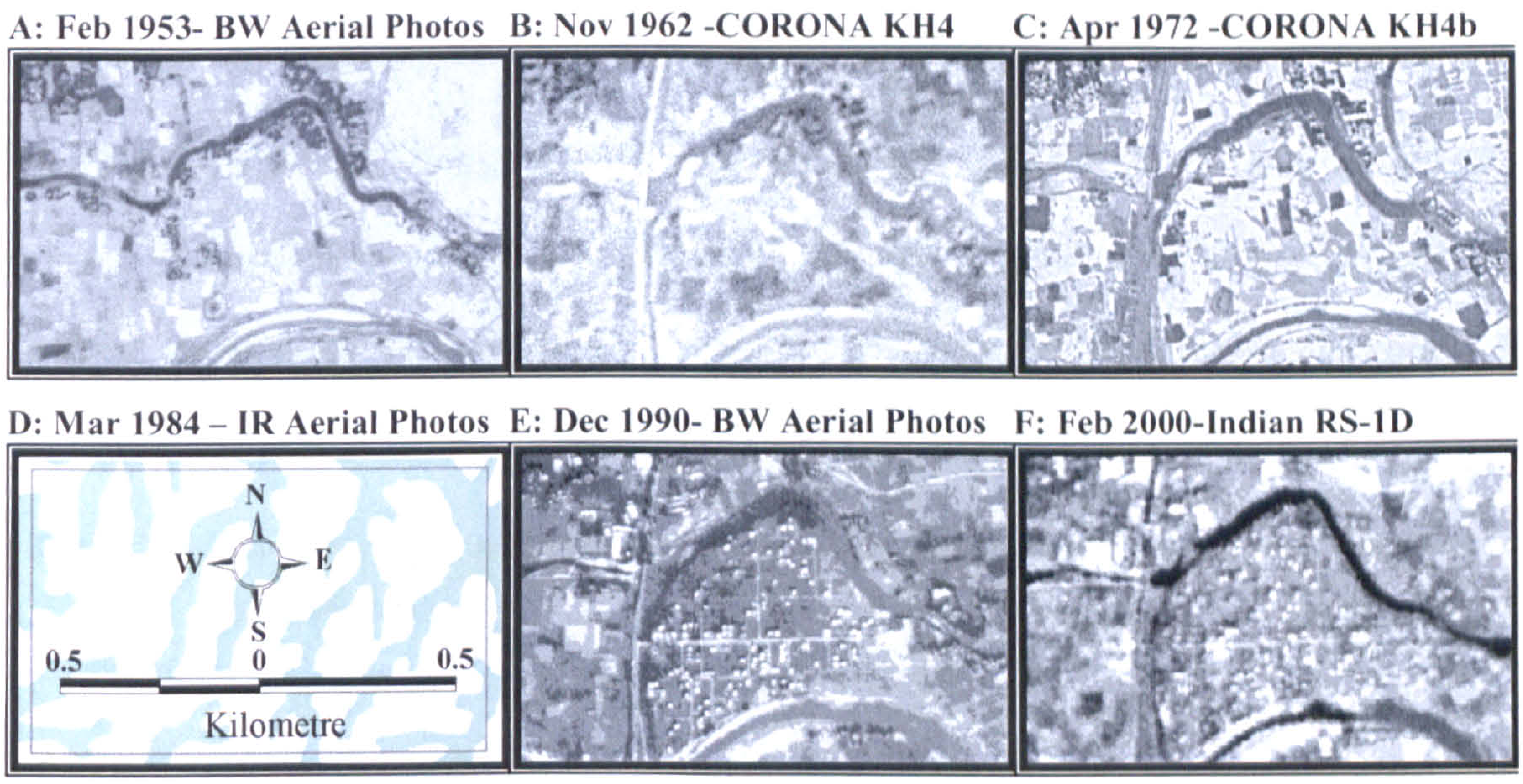


Figure 3-29: In E and F, the small dotted bright objects are the multi-storied buildings of a private housing project named Agrani Bank-Town. On both sides there are *khals*. The land was used as agricultural fields until the mid-1980s. The estate authority has provided all urban utilities. This is the only project that has been commissioned so far, though there are hundreds of housing societies in Savar upazila. The most uncomfortable side of this project is the north-western big white marks, which are dyeing industries and chemicals outlets connected to *khals* and which spread very bad smells particularly in the dry season. The 1984 clip is not available.

3.3.6. Water Bodies

Savar has a variety of large and small water bodies (Table 3-6). It has a flood plain as well as Pleistocene landmass, including natural versus artificial water resources.

Major natural changes occurred in water bodies due to river and bank erosion in the south-western part of Dhaka. Common examples of human interference are bydes converted into lakes and ponds filled in.

(a) Beels: Bara Oalia

Interpretation Techniques: In Figure 3-30 an amoeba-like shaped area, known as a *beel*, is the deepest part of the byde. The tone of beel-water varies in the images from the different sensors and seasons. But the common characteristics of the beels are: the area is surrounded by villages and there is no direct land connection between them. The texture of a *beel* is very smooth, depending on the depth of the water body. The middle part is the deepest zone and the smoothest part of the *beel*. A *beel* is not an independent feature and is connected by *khals* (tributaries) and *bydes* for its main source of water. Absence of vegetation around it indicates the maximum extent of the *beel* in the rainy season. The brightest object of the February 2000 IRS image shows the bare soils in the east, which is an early indication of activities of earth movement of a new housing project in that area.

Table 3-6: Various types of water bodies in Savar *upazila*, with their local names and characteristics.

Water bodies	Example	Duration	Comments
Beels	Oalia *Beel*	Perennial	A natural phenomenon associated with lower bydes
Sarobar & Jheel	Jahangirnagar *Sarobars*	Perennial	Upgraded from a seasonally inundated *Byde* to a perennial lake by human interference
Deghoir	Musurikhola *Deghoir*	Perennial	Abandoned course of a river
Pukur/Ponds	Yearpur Ponds	Perennial	In general, provides water in *chala* lands during dry season. The *pukurs* are created artificially.
Rivers	Bansi Rivers	Perennial	Includes entrenched (Turag) and meandering (Dhaleshwari) rivers
Khals	Karnapara *Khal*	Seasonal	Natural distributaries
Bydes		Seasonal	The extent of water margins gradually shrink in dry period

Source: Images observations and Fieldwork 2001

Background and Reconstructing the Past: The Oalia *beel* (Figure 3-30) was a part of Government Khas land since the 1950s and the then *khal* was occupied by the local influential people and recorded as their own personal property. The area is surrounded by villages and *paras*. In the wet season, the area goes 3-5 metres deep under water for 6-7 months. In the dry season, most of it become under cropping land and about 30 percent of the area remains under shallow water. The *beel* is the main source of local fish resources. The village has been connected with the Savar growth centre through narrow channels via this beel since the 1970s in the east and then connected by the road network in the west. The beel also was the perennial source of drinking water as well as for irrigation using traditional methods from the beginning.

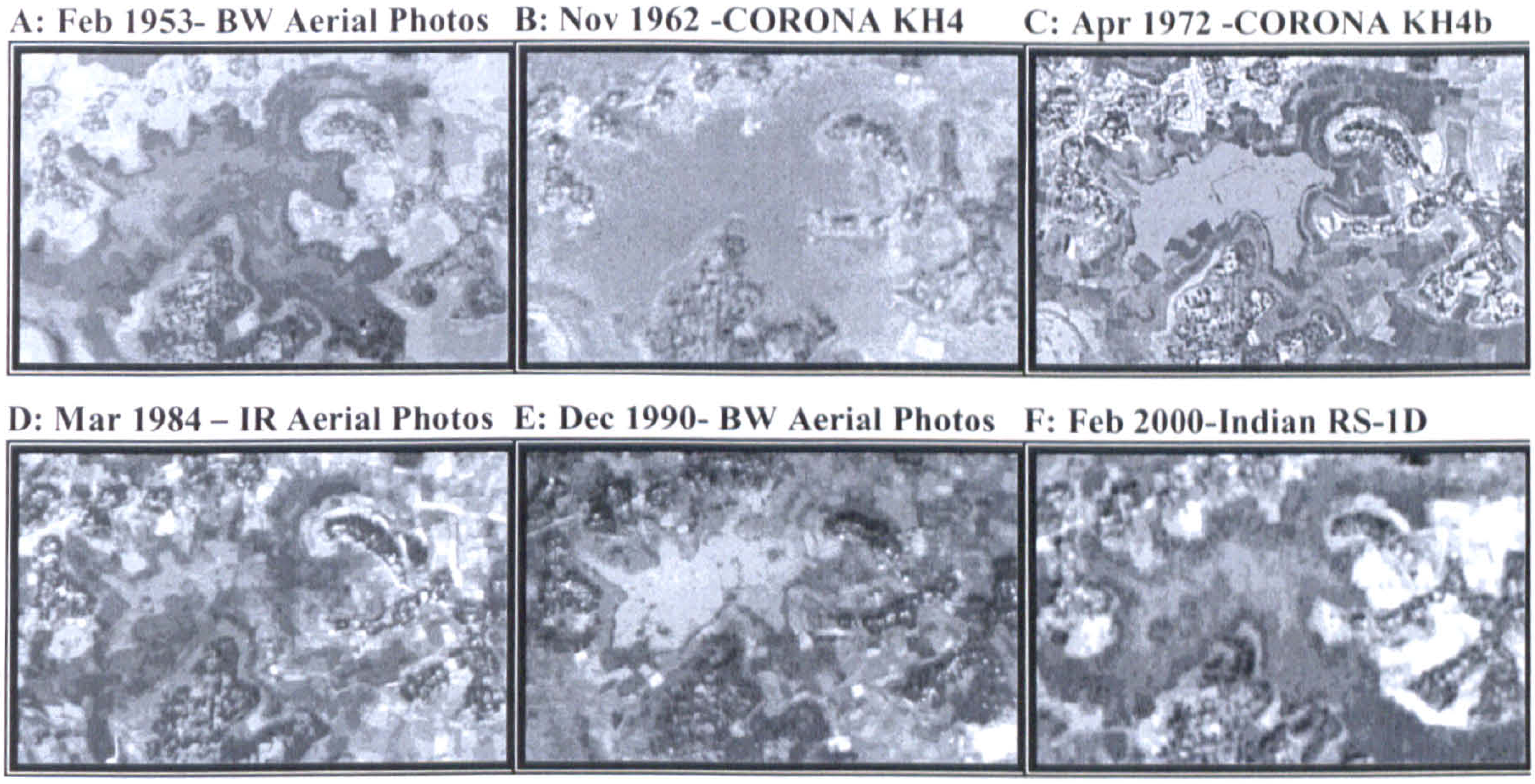


Figure 3-30: Oalia Beel is surrounded by rural settlements and *bydes* or *khals*. This perennial *beel* recharges each year by deep flooding. This is the main source of water for home, livestock and irrigation all year long. Margins of the *beel* are suitable for cultivation in the dry season as the water retreats to its deepest part.

(b) Deghoir: Uttar Musurikhola

Interpretation Techniques: A *deghoir* is the derelict part of a river but the *chars* or *kandas* enclose both sides. It has parallel long banks with trapped deep water. The adjacent long banks of the *deghoir* are not high enough to establish new settlements. Figure 3-31 shows in the northwest corner a new village that has been established in the 1980s on what in the 1950s was a deep river channel. In the 1960s, the abandoned river channel had almost vanished having once connected Dhaleshwari and Turag through a feeder channel. In 2000, the south-northward long *deghoir* had a permanent shape. There were a significant number of fish traps in the *deghoir* when the water started retreating. The *deghoir* is an integrated and remarkable part of *chars* and *naaljomis* as a source of irrigation water.

Background and Reconstructing the Past: The entire western part of Bhakurta *union* of Savar upazila includes 15 *mauzas* which are always highly vulnerable to prolonged flooding and the land features are therefore changing significantly. Musurikhola *mauza* was always at risk and the geography of Savar has been changing due to its physical disappearance in the water and then later rising up again. In general, the entire village population became homeless and their property went under water. Now the Musurikhola *deghoir* has been placed here as a compensation for the poor villagers (Figure 3-31).

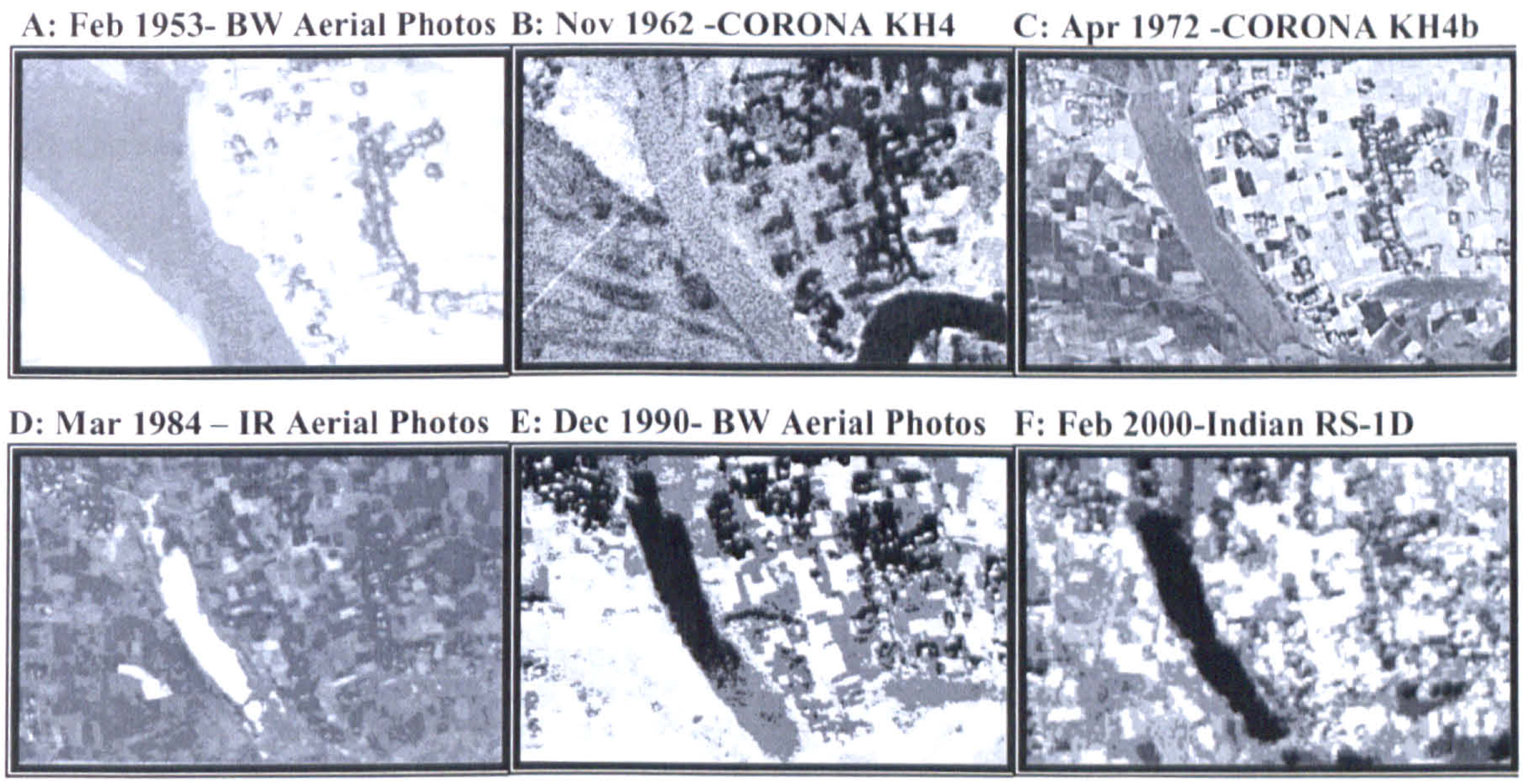


Figure 3-31: Musurikhola *deghoir* is an amusing example of trapped water abandoned by the river Dhaleshwari within a few decades. This extraordinary example demonstrates the fragility of the landscape in an active floodplain. In the southeast corner more small water bodies are also visible. The rapid shift of the Dhaleshwari River created this remarkable land feature. In the northwest corner, we can see an evolution of new village on a 1950s deep river after creating a *kanda* or natural levée. So, the *deghoir is* a part of abandoned river channel enclosed both ends by *chars*.

(c) Sarobars: at Jahangirnagar

Interpretation Techniques: How many bydes are available in the images A and F of Figure 3-32? Are all of them converted into lakes? The total areas of bydes were reduced over the time and some of them have disappeared as a result of development activities in the area. Here, in the western part of the image clips, the bydes were levelled with the chala and became a part of massive constructions. The eastern lakes remain stable except for the tip edges in the south. In the first three decades the bydes are visible as dry land with agricultural practices. But in the last decade the darker tone is an indication of a permanent water body with relatively brighter contrasts at its edges. In the recent two decades, the exposed soils indicate further development activities in the west. In order to identify the lakes, the 1984 and 2000 images show better performance.

Background and Reconstructing the Past: The following is the history of a group of *bydes*, especially how the bydes are converted as *sarobars* and major fishing resources for the local economy in even the dry season. In general in the pre-development period (until the 1970s), the bydes were almost dry and cultivated as fertile single cropping land. In the wet season they were inundated for 3-5 months. This was the traditional scenario. By the 1970s, the adjacent chala land natural vegetation covers gradually disappeared. This was the beginning of the mass land cover change. By the 1980s, the chala land was occupied by the university buildings. At that time, the university authority wanted to trap the water during the wet season. They built small submersible earth embankments in their part of the bydes.

So, the traditional agricultural fields were suddenly transformed into big reservoirs. As a result, an unpredictable thing happened; a variety of migratory birds started coming from Siberia during winter. Moreover, the lakes were later converted to fish farming. The university lakes are now the major fishing grounds in Savar, which generates money for the university as well as attracts tourists during the winter for its scenic beauty and thousands of migratory birds. Finally, from the environmental point of view, the underground water table has been raised permanently. So on the unused and deserted surrounding chala lands, an aforestation programme has been in full swing over the last few years. To keep the lake water layer stable, the university has diverted all of the used-water (by the local inhabitants) towards the converted *sarobars*.

(d) Dobas: in Ganda

Interpretation Techniques: The tones of the naturally created dobas are darker and the surroundings are very smooth without having any vegetation cover and no village around the *dobas,* as the land is flood prone. The inner and outer textures are very smooth. The natural beels are interconnected by a tributary or khal. The top edge is relatively rounded compared to the beel in the *byde*. The natural *doba* gradually merges with the surrounding land while the *byde beels* merge almost immediately with *chala*.

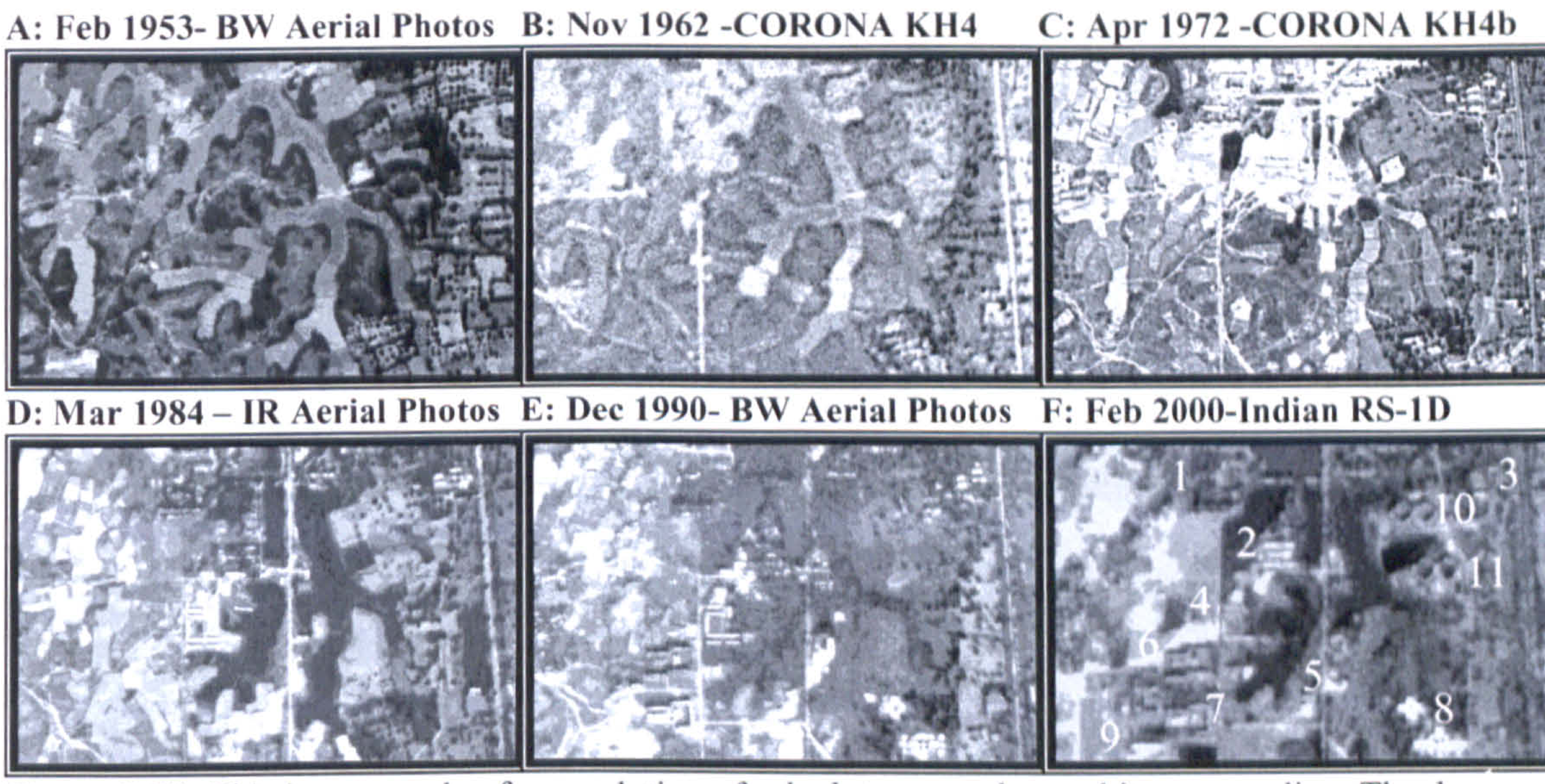


Figure 3-32: This is a example of an evolution of a *byde* to a *sarobar* and its surrounding. The deep and dissected relatively darker part is now a lake under the Jahangirnagar University authority. The major sources of used water in the F Clip keep the water table stable in dry season. **Key**: 1= Al-Beruni Hall; 2= Fazilatunnesa Hall; 3= Faizunnesa Hall; 4=Al-Beruni Extension Hall; 5= Registrar/Administrative Building 6= Salam-Barkat Hall; 7= Kamal Uddin Hall; 8= Social Sciences Buildings; 9=Bhasani Hall; 10= Jahanara Imam Hall and 11= Priti Lata Hall. (The Halls are designated residences for the university students and each hall has about a 500 student capacity)

Background and Reconstructing the Past: Figure 3-33 shows how *dobas* can be identified and also illustrates the chronological history. The lakes are known as Ganda *doba*, a combination of six smaller lakes. These *dobas* are unique in Savar upazila. Unlike the other lakes, these are not located at the bottom of bydes. The land is known as naama or depressed land. The lakes are situated on both sides of the local Karnapara *khal*. The perennial *lakes* are the major source of irrigation water in the dry season while the Karnapara *khal* was responsible for bringing fertile sediments during the flood season to the entire low land. This is how the area was the most fertile land. In the 1960s, in the middle the south-north road, with a very small underlying culvert, were constructed by dissecting the beels. This eventually changed the entire scenario of the area over the last three decades. The lakes are now isolated from each other and are treated as sumps for the most polluted chemical water from the nearby dyeing industries established over the last decade, despite government restrictions. Moreover, most of the surrounding fertile agricultural land has been replaced by settlements and housing societies.

(e) Shapla-Jheels: at National Monument

Interpretation Techniques: The monument *jheel* is the biggest example in Bangladesh. Concrete binds the banks of the jheels, which are carpeted by red ceramic bricks. So the lake (in Figure 3-26) has sharper and straighter edges in comparison to any other lake or water body in Savar. The *pucca* footpath around the *jheel* is also unusual.

Background and Reconstructing the Past: The monument *water bodies* are basically a tourist attraction, converted as *jheels* from predecessor *bydes*. There is no plan to use them for fish farming. The *jheel* is used for various coloured water lilies, the Bangladesh national flower. Here, the lakes are known as *shapla-jheels* (or lily-lakes).

(f) Pukur or Ponds: Urban vs. Rural

Interpretation Techniques: A *pukur* is a square/rectangular-shaped water body excavated by the local landlords or the then *jamindars*. In most cases pukurs are surrounded by homestead trees and houses. The bank of a *pukur* is darker than the water. The texture is very smooth in comparison to the adjacent areas. Most *pukurs* are located in *chala* land. In some cases, in the *bydes* or *chwaks*, pukur-like shapes are visible. *Pukurs* have no vegetated banks. The banks are relatively bright and the inner water bodies are relatively dark.

Background and Reconstructing the Past: There were hundreds of ponds in Savar upazila. Though the village ponds are still visible, the urban ponds are disappearing by conversion to building land. Figures 3-34 and 3-35 show *pukurs* in rural and *paurashava* areas. In the *paurashava* areas, *pukurs* disappear gradually as the people use tube-wells while in rural areas they are still considered as the main source of water in the dry seasons. The *pukurs* in *chwaks* or *bydes* have two objectives, to hold water during the dry season for irrigation and to trap the wet season fish that seek to get shelter here when the water starts retreating. The fish are trapped easily and villagers then catch them in the dry season.

(g) Rivers (Nodi): Dhaleshwari and Turag

Interpretation Techniques: River water is a relatively dark tone in all sensors except in the 1962 image where it has a light and smooth grey tone. The shape and size helps to identify this feature easily whatever the other parameters are. The river in Savar is generally more than a hundred metres wide in the dry season and increases its width more than twice in the wet season. There are several differences between entrenched and meandering rivers. Entrenched rivers flow across the *bydes* and *chalas* and do not normally change their course; the basin is known as *chwaks*. Meandering rivers flow through the *chars, naaljomis* and *kandas* and the channel is very unstable as it shifts its course. In the dry season, the basin on tract rivers remains darker due to its clayey dominance and high water-holding capacity while meanders become brighter due to a sandy dominance and no moisture-holding capacity. Figure 3-36 shows the example of an entrenched river and Figure 3-25 shows a meandering river.

Background and Reconstructing the Past: Savar has two entrenched rivers of the Madhupur Tract under the Pleistocene Terrace named Bansi (northwest) and Turag (east), and two meandering rivers of the greater Brahmaputra-Jamuna active flood plain, named Dhaleshwari (southwest) and Burhi Ganga (south). The tract rivers are stable and do not destabilise their basin while floodplain rivers are highly unpredictable and create new *chars* and lands and destroy many rural settlements throughout their catchment areas. As remotely sensed images show, the southern part of Savar is highly vulnerable to flood water due to part of an active floodplain. In general, the river narrows down due to a decrease in the amount of source waters from its upper basin. Figure 3-36 of Bansi river and 3-26 of Dhaleshwari river demonstrate the gradual shrinkage of rivers over the decades.

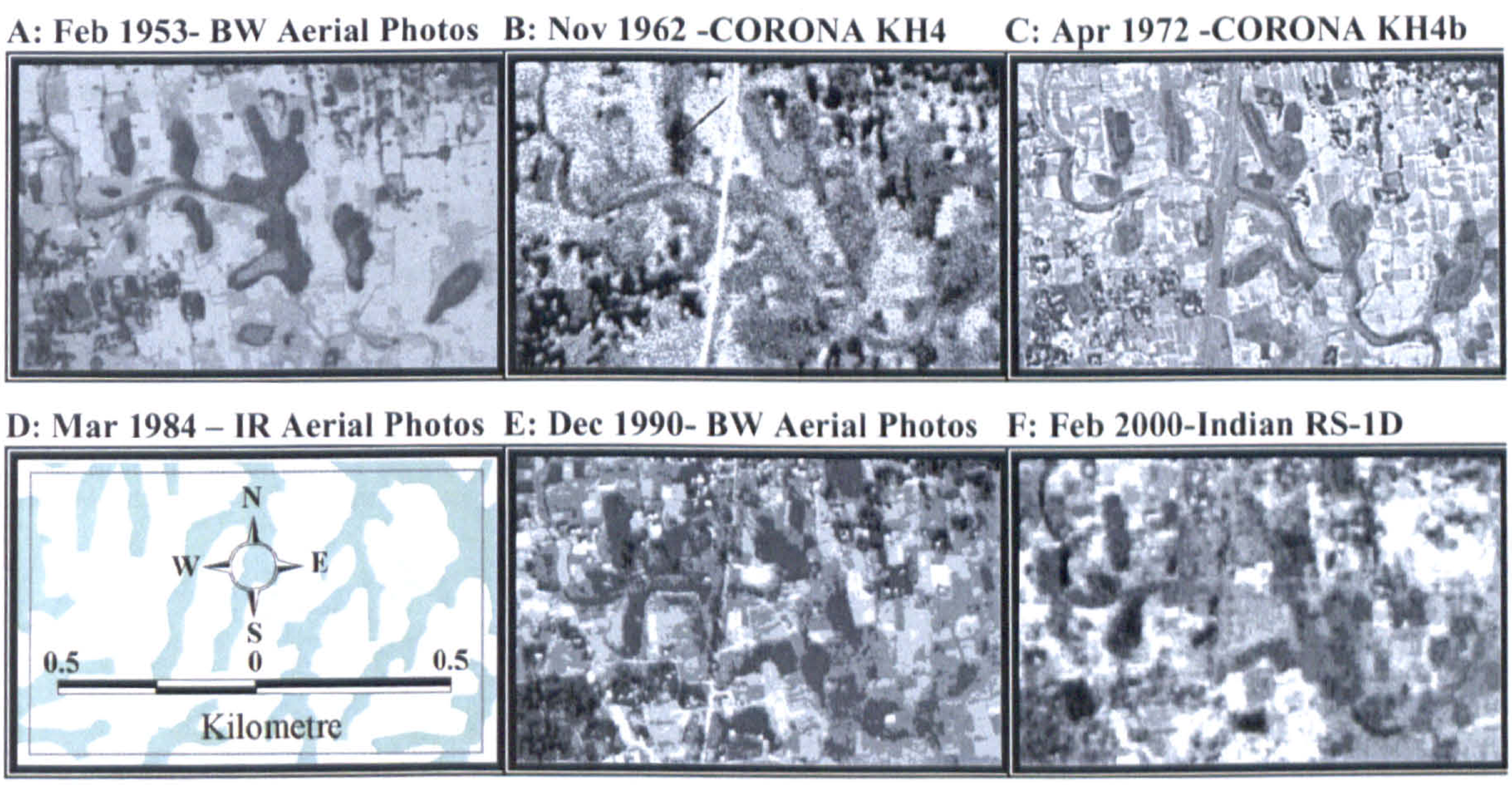


Figure 3-33: Ganda *dobas*, the dark toned water bodies, are oval shaped with the semi-detachable wings of a *khal*. *Dobas* were used for source of irrigation and homestead water requirements in anticipation of the early 1980s and after unplanned built-up of industries in this area, *dobas* are now the storage ground of industrial toxic effluents. The 1984 clip is not available.

(h) Khals: Karnapara and Karanatoli

Interpretation Techniques: Figure 3-29 shows a classical example of two *khals*. The width of the *khal* is much narrower than the river and in the dry season it may not contain water and may be used as cropping land. But the main characteristic of khals is a tributary of a river and it look like a slim channel from space. Normally it connects the rivers with other types of water bodies in the wet season. Figure 3-4 shows narrow *khals* only a few metres wide.

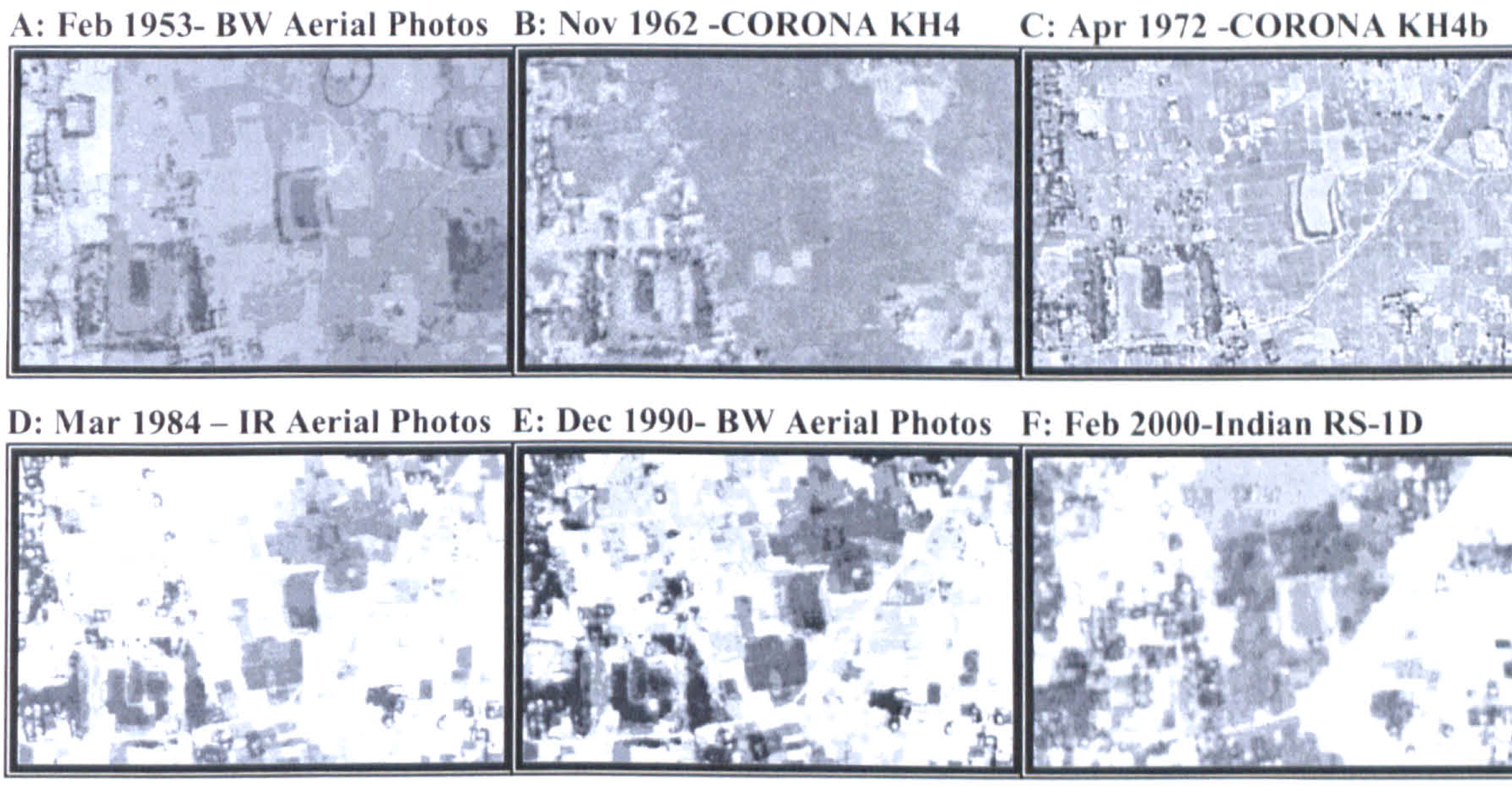


Figure 3-34: These U shaped and small other *pukurs* are in rural areas near Ghazir Chat. The southwest *pukur* is dedicated for the surrounding houses and the middle one is for agricultural irrigation purposes. The bright smooth tone indicates that the land is very dry and has a low moisture content. In general, the banks of pukurs on chalas are bounded with homestead vegetation cover and also have houses. *Pukurs* are normally rectangular.

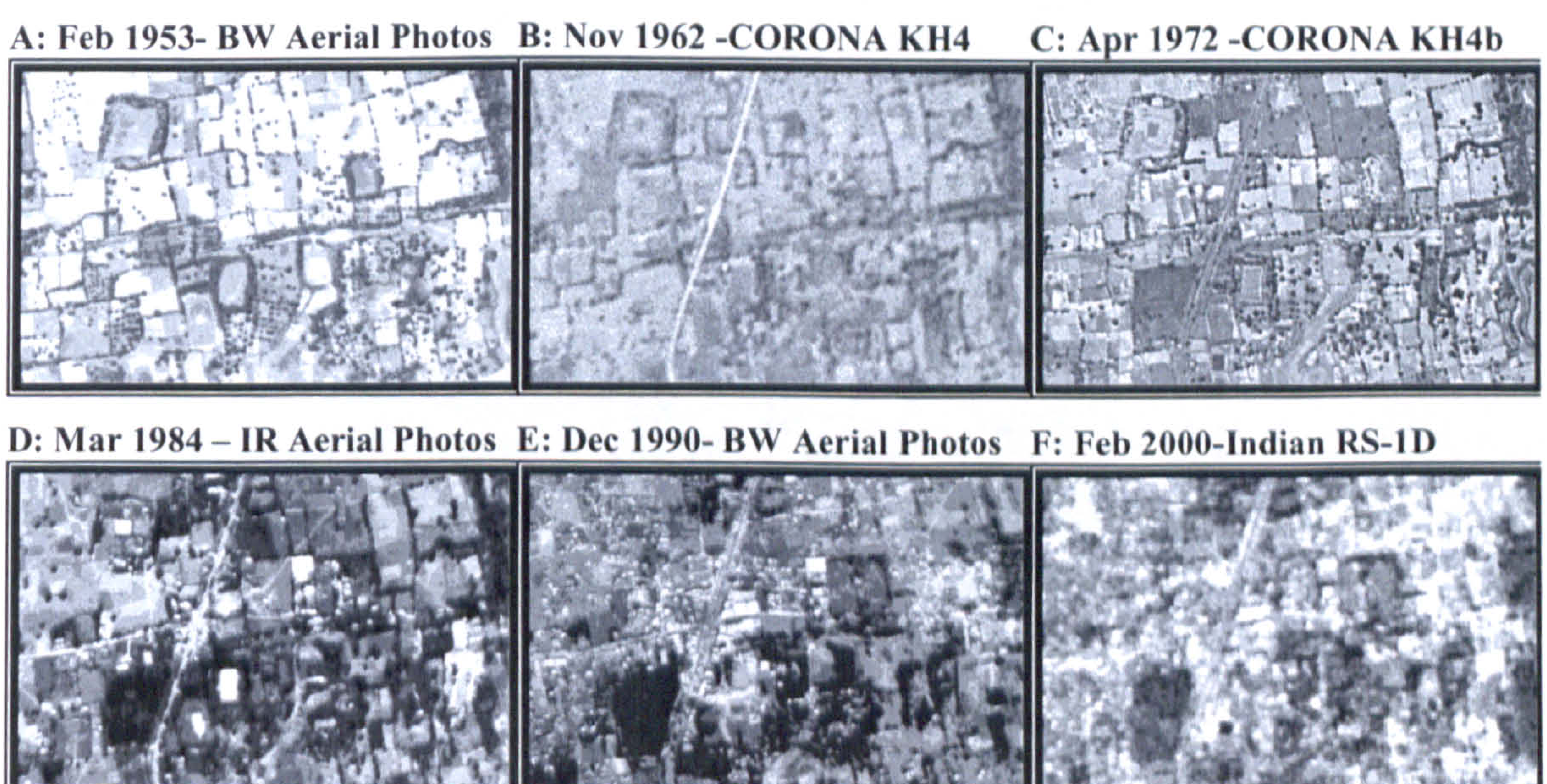


Figure 3-35: Clearly rectangular shaped *pukurs* with vegetation borders in paurashava areas are disappearing completely. The introduction of shallow tube-wells and the disappearance of agricultural land, means that the *pukurs* are not attractive to the *paurashava* people. They sell the land by converting it into housing plots to get the maximum value for the land. The above first three scenes show *pukurs* and in the last three scenes they fade away for good.

Background and Reconstructing the Past: Figure 3-29 shows the twin khals in Savar known as Karnapara *khal* (north) and Karanatoli *khal* (south). Interestingly, in the source and at the end, the *khals* combine as one channel. The *khals* are tributaries of the Dhaleshwari river and falls in Turag *chwak* or ultimately in Turag river. The local landlords and investors endanger the *khal* as they gradually capture it and construct industries illegally. So the *khals* narrow down day by day, particularly around the highway. The *khals* are highly polluted and smell badly by the outlets of the dyeing industries situated on or across the banks. Any *khal* in Bangladesh is highly vulnerable to illegitimate human intervention.

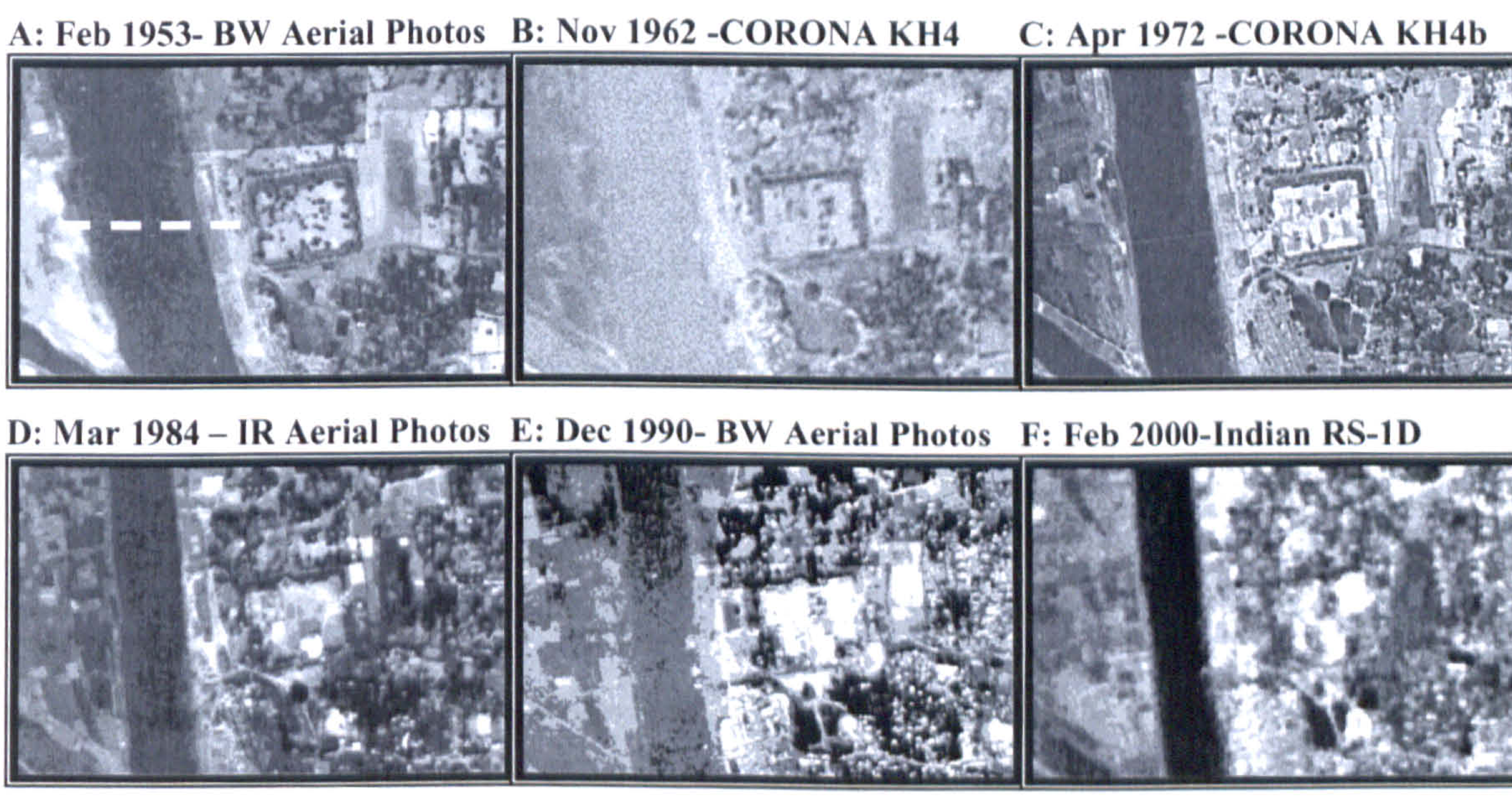


Figure 3-36: The entrenched perennial navigable Bansi River at famous Savar Bazaar (the name of Savar originated from this location) has gradually shrurk to two-third in width, which means that the water carrying capacity is also reduced. The calculated widths of the river using GIS at 23°50'52" latitude line (see the white dashed line in frame A), were 352, 347, 215, 163, 144, 137 metres in 1953, 1962, 1972, 1984, 1990 and 2000 respectively with an alarming rate of decrease. The square shaped big structure is an archaeological and historical site.

(i) Channel Disappears (Maura Nodi): at Baliarpur

Interpretation Techniques: In Figure 3-37, we can see, a bright and thin linear object that is a road which was under construction and an active feeder channel flow that was affected in the 1950s. A decade later, the road was already constructed and the river was split up and in the 1970s, the river was dying. Later the river gradually disappeared and finally abandoned its stable course. Between the 1960s and 1990s, trees were planted on both sides of the road as the dark tones indicate, but in 2000, due to widening of the road, three trees were cut down.

Background and Reconstructing the Past: In the first two decades as shown in Figure 3-37, a river is clearly visible but blocked by a newly constructed highway. In the next two decades, the river is in a dying condition and at present, it no longer exists. The whole southern river network was destabilised by the intervention and as a result several villages have gone under water due to massive riverbank erosion. For example, about five kilometres away Musurikhola village experienced such a disaster. When the river changed its course and displaced many people.

3.3.7. Industrial Belts

Savar upazila has diversified pull factors which attract population to this area. The most important reason is in establishing a number of industrial belts by the private, public and foreign investors. Amin Bazaar, Nayarhat, and Dhamsona are the three major industrial belts (Table 3-7).

Table 3-7: **Broad Industrial Belts in Savar with the type of Investors**

	Industrial Belt	Establishment	Industry	Investors
(a)	Dhamsona	Early 1990s	Dhaka EPZ-2	Foreigners under Govt Protection
(b)	Nayarhat	Mid 1970s	Heavy Plants	Public and Private Companies
(c)	Amin-Bazaar	Early 1980s	Brickfields	Private / Individual investors

Source: Field Data Collection, 2001

(a) Brickfields: Amin-Bazaar Belt

Interpretation Techniques: All of the brickfields are also rectangular in shape and a few hundred square metres in area. The hottest chimney is small in size but is the brightest part of the square boxes. The less bright two-thirds of the adjoining backyard is used for the preparation and storage of large amounts of bricks. A dark-toned depressed valley surrounds the brickfield. Bricks are made in the dry season, and in the flood period the fields are normally abandoned for several months. Brickfields need good road communications as shown in the southern part of the images, as an example (Figure 3-37).

Background and Reconstructing the Past: In the last decade, Savar is the source of bricks for much of the heavy and small construction works in and around the capital Dhaka. The Turag clay loam or clayey soil is very suitable for brick making and, due to the presence of Dhaka-Aricha national highway, there is easy access to Dhaka. Ever-increasing demand for bricks has encouraged many investors to locate their brickfields around Dhaka-Aricha highway part of Turag valley. Figure 3-37 shows the construction of Dhaka-Aricha highway in 1950. Between the 1960s and the 1980s, the area was agricultural. Since the beginning of the 1990s, the situation has completely changed. The image shows a number of brickfields. After the construction of the Ashulia road, the brickfields have expanded there also. This is a great source of air pollution for this region in the dry season. About 85 brickfields are visible in the Turag valley (Savar part), which is 80% of the total of upazila. This figure also illustrates how the Turag and

Dhaleshwari rivers have lost their connections through the construction of the Dhaka-Aricha Highway. The brickfields are also one of the most important causes of the cutting of orchards, as they use the wood in this massive demand for fuel. Though the government has banned it in Savar, wood is used as fuel but out of sight of the law-enforcing agencies due to black dealings with many brickfield owners. Though gas is available in the area, a significant number of fields are still not connected. Wood-dependent brickfields are more hazardous than gas-based ones.

(b) Foreign Investments: Export Processing Zone of Dhaka

Interpretation Techniques: The *bydes* and *chalas* were active until the 1980s. In the early 1990s, the land development work had started as shown by the bright exposed soils there. The levelling of the *bydes* and filling with additional soils was the major activity at that time. By 2000, many industries had been commissioned and the main road had been widened. The rectangular plants placed close to each other indicate a planned industrial zone, which shares all utility services together. There is a sharp grid-patterned road system inside the belt. On the image, the roofs of the huge plants reflect their smooth textures, mostly corrugated iron. The EPZ is dependent on the good road communication network.

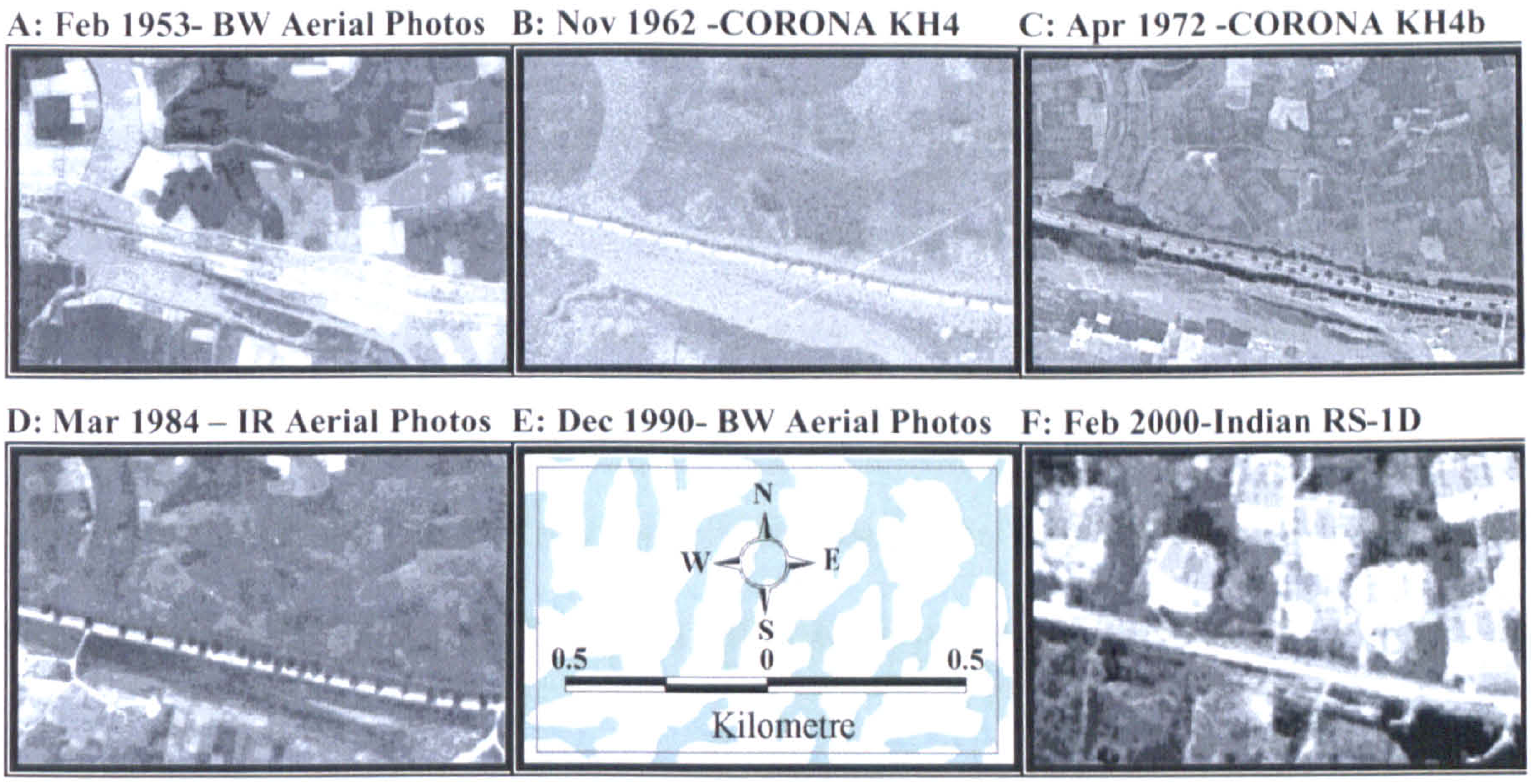


Figure 3-37: Construction of the Dhaka-Aricha Highway near Baliarpur *Mauza* in the 1950s and 1960s invited brickfield investors to the Savar part of the Turag Valley. Notice three things focus here: (1) Construction of Highway in the 1950s and 1960s, bright linear object with trees (2) river dying due to blockage of an active river channel (3) Adjoining agricultural lands converted into a vast brickfield zone. Due to heavy dust and smoke from the brickfields, this is the most polluted zone in the region in the dry period. The 1990 clip is not available.

Background and Reconstructing the Past: In F part of Figure 3-38 an export processing zone of Dhaka (EPZ-2) in Bangladesh is illustrated. It has two wings, east and west of the adjoining highway. Here the western wing is discussed as an example. The plants are the property of foreign investors, while the land is provided and managed by the government. About one hundred plants are located here. The eastern side of this wing is connected with the national highway and the western end is linked with the Bansbari *byde*. The EPZ is responsible for the enormous population employment opportunity in the region and the size of the working population has increased dramatically. Bansbari *byde* used to be a golden field of *boro* cultivation in the dry season and played a role like a *beel* in the wet season by providing fresh water fishing resources in the region. This has now been ruined by the economic giant EPZ and the *byde* is now blocked by the EPZ outlets and converted into a perennial hazardous *beel* of toxic liquid chemicals. The agricultural economy has been devastated by this industrialisation.

(c) Local Investments: Nayarhat Industrial Belt

Interpretation Techniques: Based on the feature identification techniques, we can now say for sure that in the 1950s, the area, illustrated in Figure 3-39, was mostly under *shaal* forest. In 1960s, the *bydes* and *chalas* were exposed and a road added here. In the 1970s, a few buildings were under construction near the road and a *katcha* road was constructed northward to the adjoining main road. The number of big square boxes increased by the 1980s, and since then a few *bydes* were also upgraded as *sarobars* or *pukurs*. The main complex in here is Ganashasthya Kendra (a health complex with its medicinal plants). As the buildings age, their roofs are fading from the original very bright tone but the smooth texture remains. The area is owned by private investors and they maintain their own layout-plans, so that the plants are haphazardly located and do not share common utility services in an integrated form, unlike the EPZ which has integrated services maintained by the government. Therefore, the infrastructures here in Pathalia near Nayarhat are scattered.

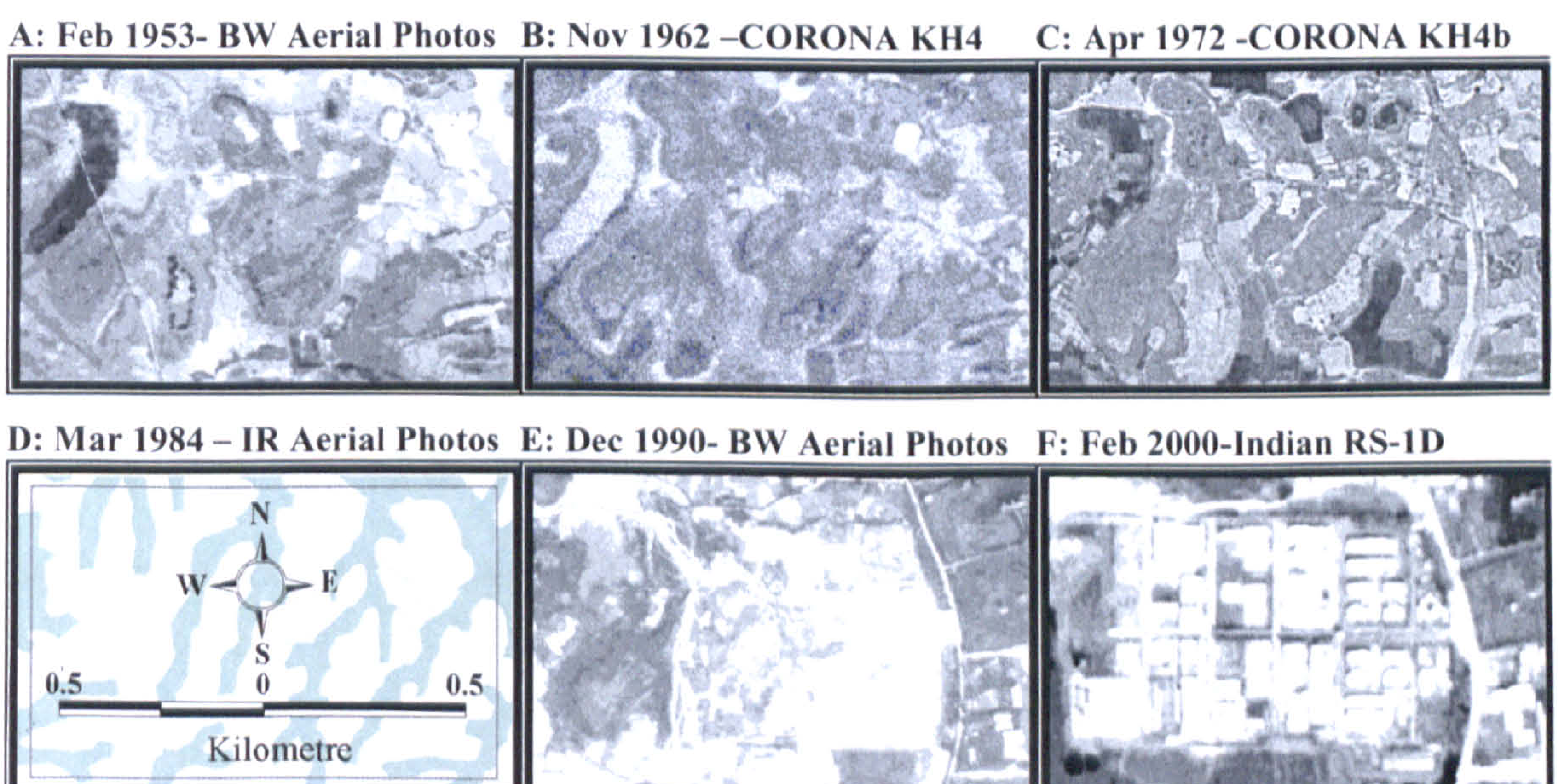


Figure 3-38: EPZ-2 (western wing) Dhaka at Ganakbari in Savar. After the commissioning of the EPZ, the area is locally known as *Raptani*. The 1984 clip is not available.

Background and Reconstructing the Past: Figure 3-39 is a private industrial belt mainly at Pathalia *mauza* known as Nayarhat industrial belt. Its history has been given in the previous section.

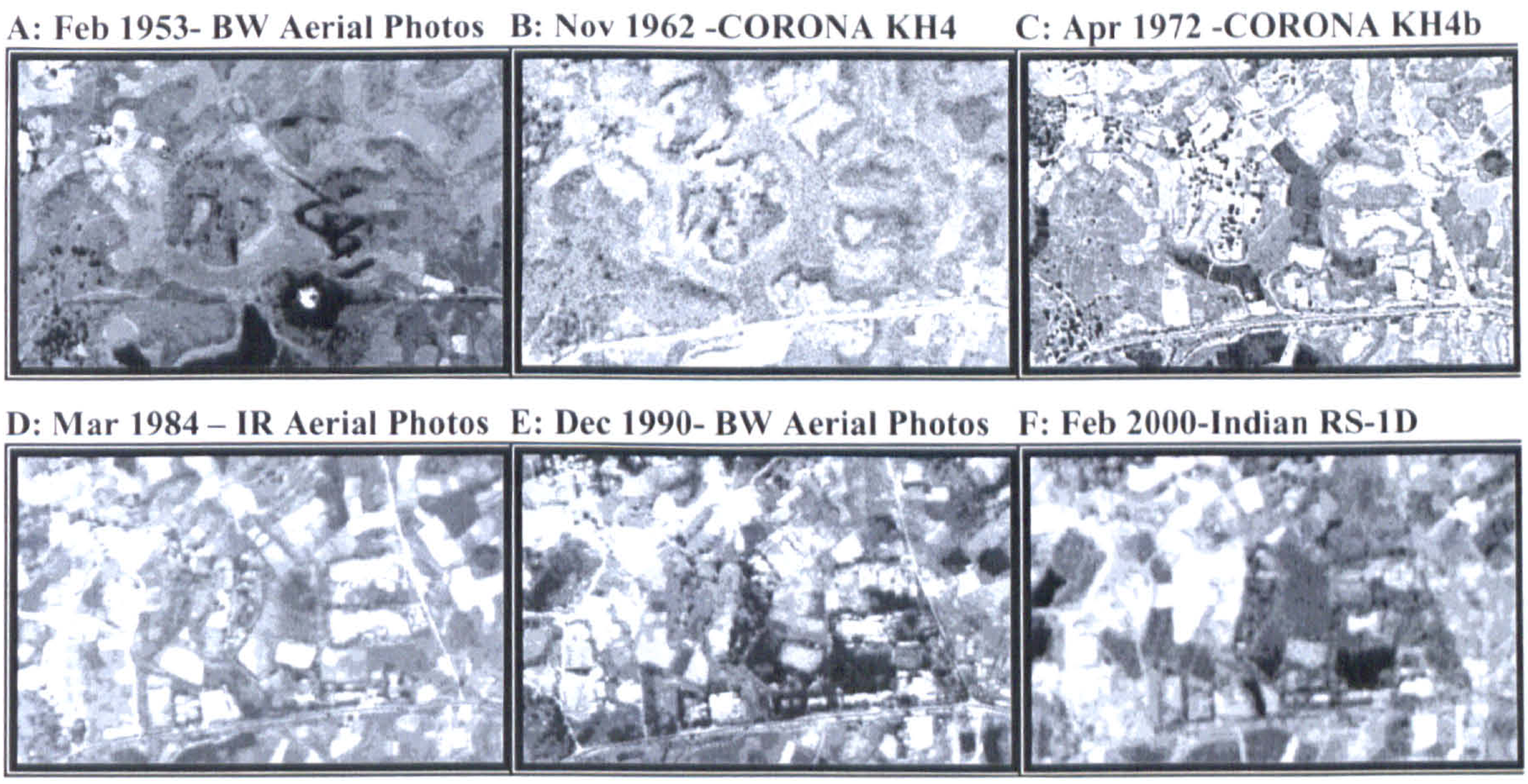


Figure 3-39: An industrial belt has been developed with the help of local investors. The area is not developed as an integrated form of industrialisation. So the industries are scattered and is still expanding towards the northwest. The southeast part already has a mature industrial structure.

3.4.0. Developing an Image Interpretation Chart

Using the above feature identification and interpretation techniques, we are able to classify each category precisely and can develop an interpretation chart which will help to identify the each land features clearly and can be used as the basis for image interpretation with other sets of data (Table 3-8). In fact, using this chart and other approaches, the further analysis and interpretations will be followed in the forthcoming chapters.

Table 3-8: **Image interpretation chart for Savar Upazila**

Feature	Shape of the Feature	Relative Size	Tone	Texture	Site	Margins or Edges	Pattern	Inundation	Association	Human interference	Comments
Chala	Irregular	Hundreds of square km	Bright	Smooth	Madhupur tract	Vegetation edge	Irregular	Flood free	Dissects by Bydes, presence of Orchards	For orchards and most development projects	Most structures are on here
Byde	Narrow passage with wings	A few km long	Medium	Smooth	Dissects *chala*, Narrow top to wide bottom Passage	Extended to orchards	Plot boundary visible	*Byde* top 3 and bottom 5 months	Mainly encircled by chala but end with water bodies	For agriculture cropping	No perennial trees visible, *boro* cultivation
Chwak	River Basin shaped	A few kilometres wide	Darkest	Fine	Eastern Savar or Turag basin	*Chala, tek* and river	Plots are visible in dry seasons	6-7 months	Rivers and *khals* and recently brickfields	Cropping practices, Pottery are bricks are suitable from its clay	No perennial vegetating cover
Char	Vast	Hundreds of square km	Bright when dry, darker when wet	Coarse	Active flood plain	Sharp with *chala* but gradual with *chwaks*	Shifting of river movement visible like arcs	5-6 months	*Kanda* and rivers	None except cultivation	No perennial vegetation
Kanda	Linear, Arc	About a km long	Dark	Fine	Natural levee	Contrasting	Follows abandoned channels	Less than a month	*Chars* and rivers	Settlements	Homestead vegetations
Shaal forest	*Chala* top shaped	Extended to bydes	Dark	Smooth	Chala	Sharp and contrasting	Irregular	Not affected by flood	Surrounding bydes	Deforestations	Mostly deserted, replaced by orchards

Feature	Shape of the Feature	Relative Size	Tone	Texture	Site	Margins or Edges	Pattern	Inundation	Association	Human interference	Comments
Kathal-bagan	*Chala* shaped	Size of Chala	Dark	Rough	Chala	Extended to Byde	Series of line and rows	Flood free	Orchard edges are ended with settlements	Started decreasing	Now most vulnerable trees
Bansh-jhar	Plot shaped	Hundreds of square metres	Dark	Rough	Chala	Straight Line	Compact	Flood free	Nearby settlements	Cared for by humans	Expanding perennial vegetation
Ghash Khila	Regular, rectangular	About a square km per plot	Medium Dark, feature beneath visible	Smooth	*Chala* and byde	Straight line	A series of rectangular	Flood free	*Chala* and bydes	Human dependent	Seasonal Crops cultivation
Fausholi-jomi	Small fragmented square shaped	A few decimals	Depending on land types	Smooth	*Byde* and chwak	Straight lines, eyeel	A grid of agricultural plots	1-6 months	Irrigation facilities	Human dependent	1 to 3 crop cultivation
Homestead forest	Extrovert	A few acres	Dark	Very rough	*Chala* and kanda	Zigzag, irregular	Very compact vegetation	Flood free	*Chala and kanda*	Introduced by Human	Perennial compact tree
Bare Soil	Irregular	A few hundred sq metres	Very bright	Smooth	Mainly *chala*	Vegetated cover	Irregular poly shape	Flood free	Development sites	High	Construction sites
Pucca Road	Narrow and linear	Long and thin	Brightest during construction and dark after a few years	Smooth	Connecting growth centres	Trees both sides or bare soils	Single and continuous	Normally above flood level	Bridges and infrastructures	Highways and feeder roads	Road is the primary factors for deforestation and developments
Katcha Road	Narrow and liner	Smaller than *pucca* roads	Relatively bright	Smooth	Connecting villages	Orchards and rural settlements	Following the plot boundaries	Both flood free and seasonal flooding	Bare soils	Mainly used by bullocks-cark and rickshaw vans	Planted trees on both sides

Feature	Shape of the Feature	Relative Size	Tone	Texture	Site	Margins or Edges	Pattern	Inundation	Association	Human interference	Comments
Bridges	Small rectangular	A few hundreds square metres	Medium Dark	Smooth	On rivers	Sharp	Linear	Flood free	Roads, Khals and rivers	An RCC structure	Lone permanent feature on river or *khals*
Gaon	Irregular and long	A few km^2	Dark with bright spots	Very rough	*Chalas*	*Bydes*	Dense near *bydes* and sparse inner inside	Flood free	Highly merged with homestead vegetations	Rural settlements and homestead vegetations	A mixed vegetation covers
Dia	Almost round shaped	Less than a km^2	Dark with bright spots	Very rough	*Tek*	Starting of *chwak*	Distant from the mainland *chala*	Generally flood free	Cropping field or flood water	Rural settlements and homestead vegetations	Like an island in wet season
Kandi	A linear or arc shaped	Less than a km^2	Dark with bright spots	Very rough	*Kanda*	*Chars*	Abandoned channels of rivers	Flood prone	Rivers and natural levees	Rural settlements and homestead vegetations	Reflecting Clear Shadow northward
Parks	A very geometric designed	Less than a km^2	Medium dark tone with bright intersections	Even	*Chalas*	Lakes with sharp edge	Complex linear intersections	Flood free	Dark Lakes and bright structures	Concrete passage and monument	very picturesque
Paurashava	Irregular	Relatively large settlement zone	Remarkable mixed with bright spots	Vastly rough	*Chalas*	Flood level	A compact settlements	Stagnant of water due to poor drainage in wet season	Roads and Mass population density	Flats are made of *pucca* roofs and walls	No /little homestead vegetation
Town	Poly-Linear outer shapes	A few km^2 complex	Constructions: New-bright; old- dark	Overall rough but individuals are smooth	*Chalas*	Starting of Villages, linear	Various Geometric Patterns	No	Roads and Parks	Heavily Developed	Little perennial trees, shadows are visible
Housing	Bright grids	A few sq km complex	Bright	Smooth	Mainly *chalas* and upper bydes	Vegetation edge or water bodies	Linear Grid roads	Generally flood free	Small roads and pucca houses	The land is levelled	No Vegetation

Feature	Shape of the Feature	Relative Size	Tone	Texture	Site	Margins or Edges	Pattern	Inundation	Association	Human interference	Comments
Beel	Almost amoeba like	Less than a km^2	Medium	Very smooth	Lower *byde*	Emerging *chala*	Funnel like	Natural Perennial water body	*Chalas* and *khals*	No interference	Availability of Hydroponics
Deghoir	Rounded rectangular	More than hundred square metres	Dark or grey	Smooth	*Chars*	Distinctive	Abandoned channel	Natural Perennial water body	*Char* lands or *naaljomi*	No interference	In and around no vegetation
Sarobar	Arced Rectangular Byde	About hundred square metres	Dark	Smooth	Upper *bydes*	Relatively sharp and clear	Dendritic Pattern	Upgraded from seasonal to perennial water body	*Chala*	Upgraded by owners	Generally no vegetation cover
Dobas	Oval or balloon	About hundred square metres	Dark	Smooth	Lower byde	Very smooth	Wing of *khal*	Submersible perennial	*Khals*	Wasteland or no direct use, sometime in-filled	Only visible in dry season
Jheel	Sharp rectangular	About hundred square metres	Dark	Very smooth	In a park or recreational place	Sharpest edge	90 degree angular corners	Perennial but flood free	Concrete foot path	Under Constant Supervisions	Not used for fish farming
Pukur	Square or Rectangular	Smallest water body	Grey	Smooth	Inside *para* or farmland	Generally enclosed with houses	90 degree angular corners	Perennial but may dry in drought	Settlements on *chala* land	Excavated land	Used for source of drinking water in the past
River	Longest and wide channel	Massive	Grey or dark	Smooth	Very Lowland	Sharp in Dry season	Meandering or entrenched	Perennial	*Chars* and *Chwaks*	None or embankments	Source of flood water in monsoon
Khal	Short and narrow channel	A few km long	Dark	Smooth	Lowlands	Clear if watered, fuzzy if not	Linear or meandering	Overflow in the wet season	*Chars* or *chwaks*	Vulnerable to illegitimate interventions	Industrial outlets are linked with *khals*

Feature	Shape of the Feature	Relative Size	Tone	Texture	Site	Margins or Edges	Pattern	Inundation	Association	Human interference	Comments
Brickfield	Square shaped	About a few hundred km^2	Very bright with the brightest head	Smooth head and rough backyard	*Chwaks*	Very clear and contrasting	Scattered square fields	Submerged during floods	*Chwaks*, *pucca* roads and highways	Owned by local landlords	A source of air pollution in dry period
EPZ	A group of rectangles	Industrial plant sized	Bright	Very smooth	Highlands	Clear and sharp	Organized and integrated	Flood free	Roads and outlet *bydes*	Foreign investors	A very labour intensive industrial zone
Industries	A few rectangles	Industrial plant sized	Moderate bright	Smooth	Highlands	Clear	Disorganised	Flood free	*Chalas*	Local investors	Mainly local unplanned industries
Plot	Gridded lines and columns	A few square metres	Grey, bright if bare soils	Rough	Agricultural crop lands	Bounded with *eyeels*	Gridded with land types	Seasonal flooding	Water bodies and lowlands	Mainly for cultivation	*Chala* plots are suitable for housing

Source: based on Image Interpretations and Fieldwork, 2001

3.5.0. Conclusions

We will now be able to identify the common land features for further analysis, from satellite images and air photos and ground verification during fieldwork in 2001. Each feature has a context that is visible from the air and space, which helps us to understand the evolution of a feature. We can summarise all the basic land features in a table with their basic interpretation techniques and draw a generalised land transformation model on the basis of the major land cover changes identified.

The study area is changing over time phase by phase. Different factors are responsible for that and we can assume a preliminary time frame for its transformation. From interpretations based on the remotely sensed images, we can identify three major phases of developments in Savar upazila. These major **'temporal development phases'** can be suggested as follows:

Stage 1: ***Pre-development Phase (until 1961):*** no construction work and infrastructure or pucca roads have been seen on the image and the entire society was dependent on agricultural activities and used to use waterways for transportation and communication;

Stage 2: ***Developing Phase (between 1961-1991):*** the major land acquisition has taken plan in this time and most of the basic infrastructures for development have been either planned or initiated including construction of highways, land acquisition for infrastructure developments and so on; and

Stage 3: ***Pro-urban Phase (since 1991):*** the urbanisation has started in this period and likely to be a fully urbanised area in a couple of decades.

I will discuss the phases also based on the population census data and land value in the coming chapters as additional attributes of remote sensing data. The attributes cannot explain the context while remote sensing cannot see the attributes directly. So the GIS and Image Data can play a complementary role to each other in order to make a bridge between them and open a new field of pixelising social data and socialising pixels. If we construct phases of development in the context of space, we have a set of **'spatio-historical phases'**.

By observation and interpretation of the images with appropriate skill and local knowledge, the past of Savar upazila and its chronological development has been reconstructed in Figure 3-40. A total of seven phases can be visualised in this context. It must be mentioned here that most of the significant changes have happened on the chala land, which is flood free. Therefore, the location of *chala* land and its associated *bydes* is the most important deciding factor of development.

The most rapid change was initiated in the 1990s. However, without the mass-scale land acquisitions of the 1960s, the face of development and infrastructure at government level would be a very different one. We can see it as a linear feature, the Dhaka-Aricha highway in the 1970s which has opened the land to immigrants. In the 1980s, the university, monument and Senanibas have flourished as landmark features, but in the 1990s, the initiation of the EPZ and declaration of Savar as a *paurashava* encouraged the most important phase for pro-urbanisation. Since 2000, the crucial history of Savar is over and a new era of development has started. For this we need integrated development guidelines and we will consider the RAJUK master plan in this case to sketch a future for Savar.

Reconstructing the History: An Overall Generalisation

Phase 1: The area was a deep Shaal Forest. No intervention by humans. It was the home of a local ecosystem, animal kingdom and associated habitat. (Duration: unchanged for thousands of years)

Phase 2: The forest was cleared by the early settlers or nearby local tribes. The govt-lands were under the jurisdiction of the local people for the first time ever. (Duration: a few decades after deforestation)

Phase 3: Early settlers planted trees to develop orchards (mainly jackfruits) in order to meet the food shortage during the crisis season at that time and to make it more inhabitable. (Duration: at least two decades)

Phase 4: Orchards reached a mature stage and the fruits were treated as crops. Moreover the dead braches were used for fires and leaves for the livestock. (Duration: At least 5 decades)

Phase 5: Settlers planted bamboos and other vegetations to develop a Village. For indigenous homes, bamboos are the most important construction materials. (Duration: a few decades)

Phase 6: The village reached a mature stage but the nearby urban migrants started buying the peripheral lands and endangering the main village. (Duration: a few generations)

Phase 7: The Village and Orchards disappeared. The villagers sold the valuable timber to the nearby Saw Mills to get extra money before selling the land to the urban people or acquired by the government. Land cover soils are highly exposed at this stage. (Duration: a decade or less)

Phase 8a with **1st alternative:** The area gradually becomes as a *paurashava*. This is a natural growth of an unplanned town in Bangladesh context and the most likely case. The population increased rapidly before getting the basic urban services. (Duration: it takes decades to reach this stage)

Phase 8b with **2nd alternative:** The area developed by the Govt as a planned town with all facilities. It could be a classified zone or any town initiated and supported by the government authority (Duration: it takes about a decade by the government planning and funding)

Phase 8c with **3rd alternative:** A planned farming system has been developed with modern irrigation facilities. The plot size is much bigger than the traditional plot size. The shape is also very regular. (Duration: it takes about a decade by the govt or by any big investor)

Phase 8d with **4th alternative:** An industrial belt has emerged. This would be the major source of income for the local and surrounding economy. This will attract more population for the already exhausted zone. (Duration: it takes about a decade by the govt)

Phase 8e with **5th alternative:** An attractive recreational centre can be developed. Even from the sky, most of the park or open recreation sites look attractive, though it is the least likely case for any area in Bangladesh. (Duration: it takes about a decade by the govt)

Figure 3-40: From a deep forest, reconstruction of the simplified past history and its major pro-urbanisation phases as seen from the sky including an estimated duration for each segment. Phase 7, the final stage of development, is shown with several alternatives as examples.

Chapter 4

CHAPTER 4: SPATIO-TEMPORAL ANALYSIS OF POPULATION CHANGE

4.1.0. Introduction

Like remote sensing, the population censuses are also vast sources of information. Before the availability of high-resolution satellite data, it was very difficult to integrate census data with their physiographic context. If they could be made to complement each other, new fields of study would open up for social scientists, remote sensing experts, policy makers, environmental analysts, and development specialists. But the question is how and whether it is possible to make them complementary sources of information. The decennial census database is available in most countries of the world but the question remains whether parallel data is available to understand the complexity of land use at a very local scale.

This section of the current research focuses on this issue with an exploration of theoretical and practical solutions and/or practical guidelines. Amongst the two vast fields of core data, that is remote sensing and GIS (Figure 4-1), they both have complementary limitations, which will be examined in this chapter:

(1) *Remote sensing cannot see the human population and their social characteristics* (e.g. education, age, gender, religion, race, occupation etc with total figures) *directly with its electromagnetic sensors, while population censuses cannot see the spatial context and distribution of geographic features* (e.g. land types, water bodies, settlement pattern, vegetation and agricultural fields, infrastructures including road networks, and so on). Integrating the two would make an opportunity to develop metadata for the census data and vice versa.

(2) If both sets of data could be shared by using a common platform (e.g. GIS), a distinct frontier of scientific knowledge could be opened. Also, if we could use the

both datasets at a decennial temporal scale over a reasonable period in a certain area, it could open the gate of understating spatio-temporal intricacy with interrelated socio-physical transitional complexities. Some methods need to be developed to understand the link between these two platforms.

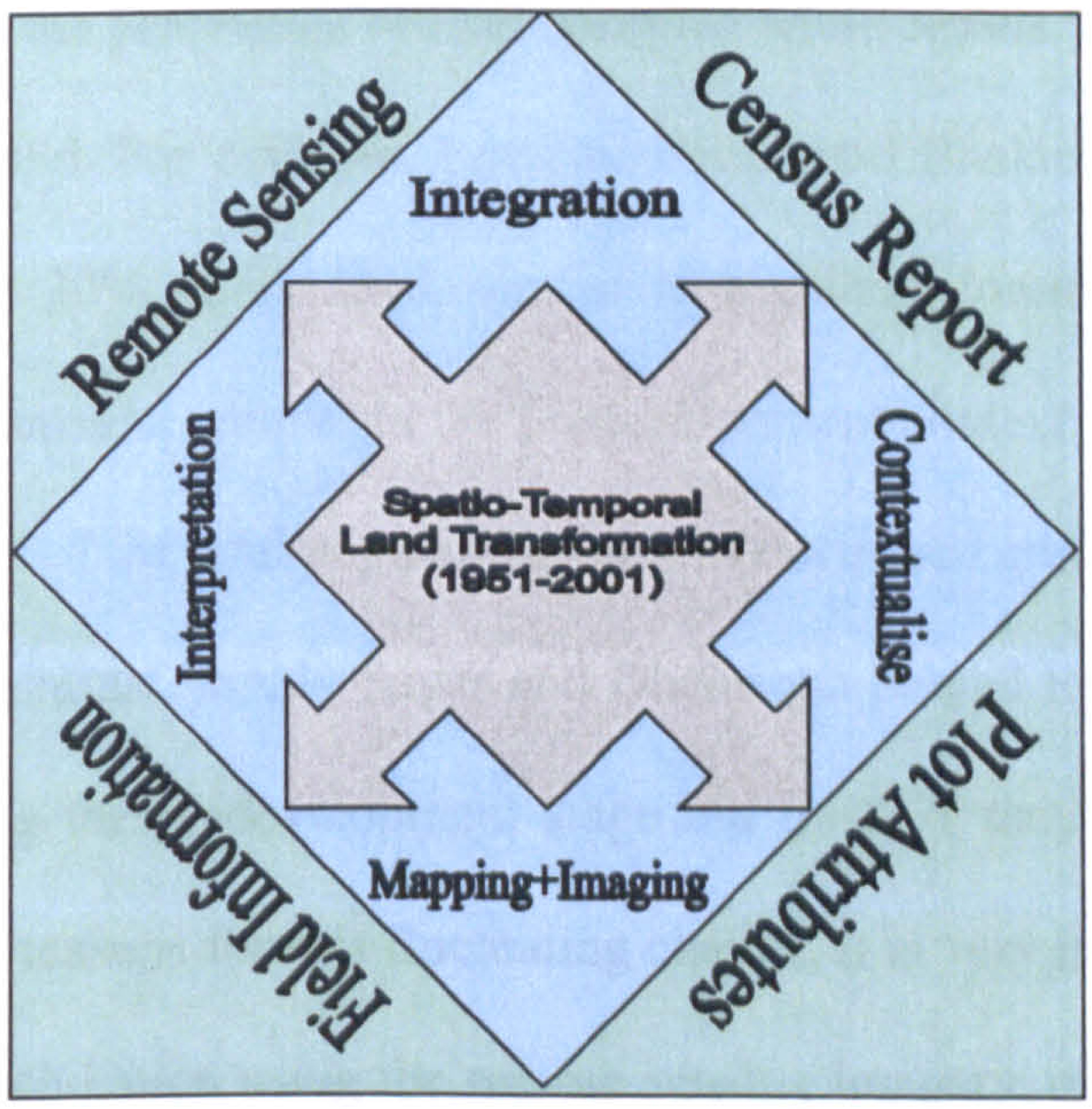


Figure 4-1: Four components have been identified for the current research framework. In the previous chapter, my main focus was on remote sensing and now we will focus on the comparison of census data with the robustness of remote sensing images. In the next chapters, field information and plot attributes will be highlighted. 'Remote Sensing and the Census' are the root of my **core** data while 'plot and field info' are the **auxiliary** data.

These two vast sources of data could help to narrow down the gap between the disciplines of remote sensing and social sciences. It is important to note here that there could be a very good bridge between the census and remotely sensed images. If we can identify various types of settlements, which are directly linked to census data, then this will give a basis to understand the censual context of the satellite/air images and establish a meaningful link between them. So in this chapter, based on the feature interpretation and identification techniques mentioned in the previous chapter, we will try to establish a meaningful bond between the two.

Figure 4-2 is a good starting point for this chapter and it will help to understand the reality of land transformation through an uneven population explosion in the upazila. The distribution of population has changed over time at the Union level of Savar upazila. The 'area' column shows the percentage of land occupied while census years show the share of population on that land. For example, Lowland dominated Bhakurta and Simulia unions together share about 20% of the land, similar to highland dominated Savar (including Paurashava) and Dhamsona unions. In the predevelopment context, Bhakurta and Simulia took about 30 percent of the total population, but this decreased gradually during the phase of urbanisation. In contrast, jointly Savar and Dhamsona pooled less about 15 percent of the population during the predevelopment stage but in 2001 they housed more than 30 percent. To discover reasons for this fluctuating change, it is very important to understand the context of the each Union using the remote sensing imagery, and, as a result, the real picture of population growth with its local complexities will be unveiled.

The chapter aims to make census data more adaptable for the researcher and planner and to give remote sensing data an additional dimension for the social scientists by adding census values.

(a) Census and Bangladesh

In general, the population of Bangladesh is increasing rapidly in comparison to any developed country. But the population growth is not evenly distributed. In and around the big saturated cities (e.g. Dhaka and Chittagong), the pressure of population is very high. Savar is a good example. Table 4-1 shows comparative statistics of population density per square kilometre over time at various administrative levels. Savar upazila (sub-district) belongs to Dhaka Division and Dhaka Zila (District).

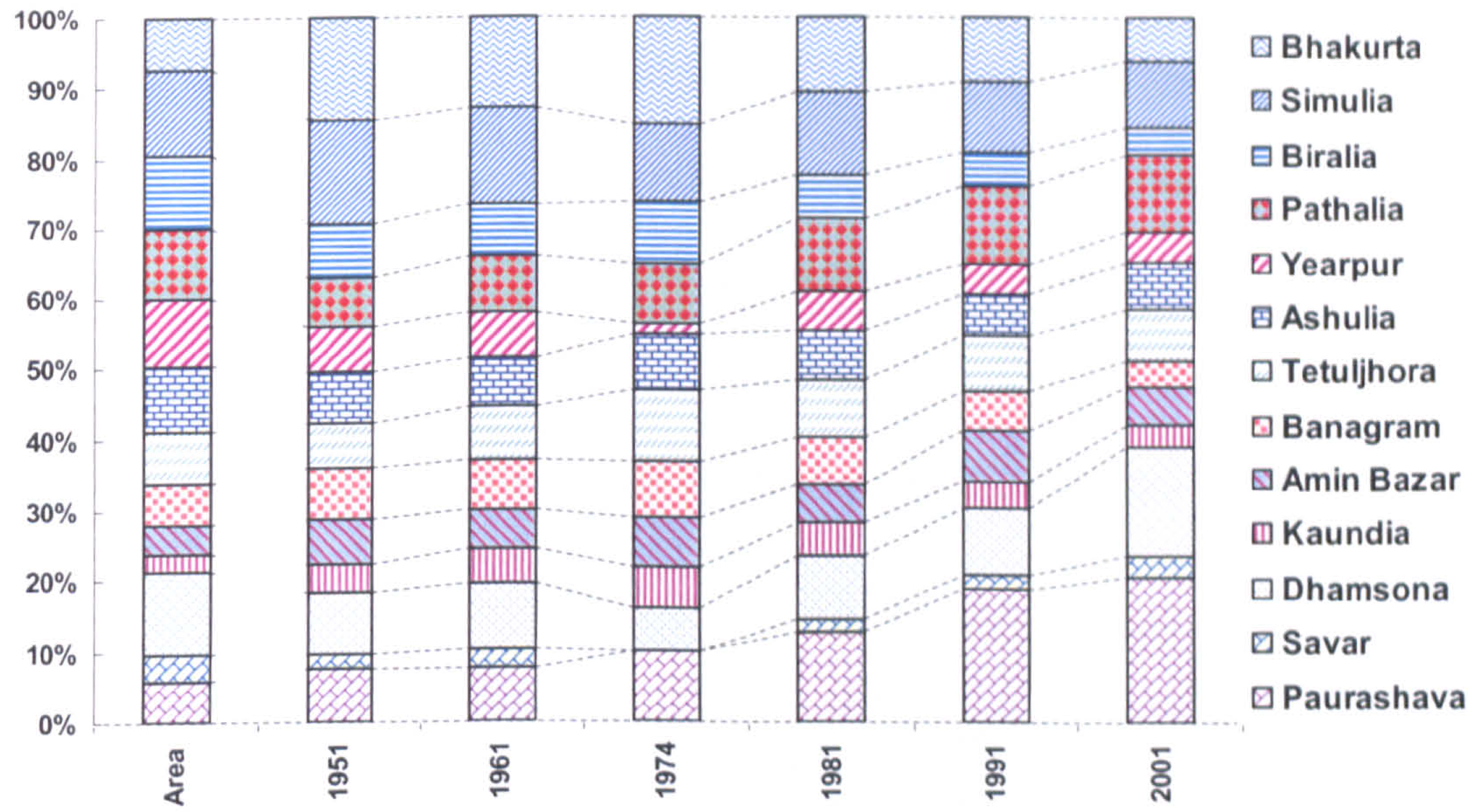


Figure 4-2: A unionwise population proportion and shared land of Savar upazila. This graph can be considered as the root and central focus of the all arguments explained in this chapter. The x-axis is mainly for the census year and the Y-axis is their corresponding share of land. The 'area' bar gives a glimpse of land-man lopsided ratio. The index shows the name of Union of Savar upazila in accordance with the symbols.

Table 4-1: Density of population/km^2 at different administrative hierarchies of Bangladesh

Census Year	Bangladesh	Dhaka Division	Dhaka District	Savar Upazila
1951	284	404	726	363
1961	345	491	999	464
1974	484	685	1882	469
1981	590	843	2,749	892
1991	720	1050	3,990	1,290
2001**	834	1304	5,859	2,240
Area in km^2	147,570.98	33,380.52	1,463.66	**284.63**

Sources: GoP 1956 and 1964; BBS 1979, 1985, 1994
**Unpublished (restricted) census survey 'Summary Forms 7 and 8' for Savar Upazila 2001*
***Census 2001: Primary Report (The Daily Janakantha, 24-Aug-2001)*

Savar has always had a higher population density than the national average because it has had relatively more positive factors at least since 1951 to attract additional people. The gap between the national average and the growth rate of Savar is widening at an increasing rate. It has now overtaken the growth rate of Dhaka division. Savar is located on the boundary of Dhaka metropolitan city; therefore the stress of Dhaka means pressure on the pro-village land of Savar. According to Table 4-1 the study area is changing and detailed census data can give a further clue how within the jurisdiction of Savar upazila the population is distributed. In 1991, Dhaka City Corporation (DCC) had 3,568,099 people, although the size is almost equivalent to all the highland (141.97 km^2) in Savar upazila with a density 25,133 per km^2, which means that DCC had a 20 times higher population density. I do not have the published data for 2001, this density has also increased dramatically over the last decade. There is no doubt this extraordinarily high density is spilling over throughout the surrounding peripheries such as Savar upazila.

Table 4-1 is not only a reflection of the population pressure on Savar upazila but also a primary indication of land-cover, including land use changes. If there were a similar increase of population data with national average, it could indicate the stable land cover change situation. For example, decennial population densities of Bangladesh between 1951 and 2001 were 284, 345, 484, 590, 720 and 834 per km^2 respectively, figures that are much lower than the Savar averages. If Savar were the same density as these, the overall land use change could be termed as proportionate or stable transform. The massive population growth in this region is behind much of the observable change. This chapter will highlight these issues as a basis for the forthcoming chapters.

It should be noted here that the quality of census data in Bangladesh, like in other developing countries, is not beyond reproach. Remote sensing can play a role in verifying the quality of the data.

(b) A Brief Outline of 2001 Census Data

The last census survey was conducted in 2001, but it is yet to be published. In order to carry out this research I collected this information from anonymous sources. This data will probably not be published for a few years. In Table 4-2, the total population, including number of males and females is shown. Without having the 2001 census dataset, it would be impossible to understand the current impact of land transformation systems on the last decade's population growth.

The Union wise distribution of the 14th decennial population census data were collected in situ from anonymous sources during the conduct of my survey between 23 and 27 January 2001. The following data are supposed to be published by 2004.

Table 4-2: Basic population data of 2001 census at Union level

Administrative Unit	*Population 2001*	*Male 2001*	*Female 2001*	*Household 2001*
Amin bazaar Union	33,140	17,440	15,700	7,112
Ashulia Union	43,804	22,877	20,927	11,206
Banagram Union	25,200	13,202	11,998	5,242
Bhakurta Union	38,025	19,760	18,265	7,583
Biralia Union	24,917	12,744	12,173	5,136
Dhamsona Union	98,764	55,820	42,944	19,622
Kaundia Union	20,463	10,324	10,139	4,321
Pathalia Union	69,656	37,016	32,640	14,791
Savar Paurashava*	132,435	69,918	62,517	30,511
Savar Union	16,957	8,702	8,255	3,717
Simulia Union	59,966	36,049	23,917	10,867
Tetuljhora Union	45,137	24,791	20,346	9,608
Yearpur Union	27,044	14,327	12,717	5,985
Grand Total	**635,508**	**342,969**	**292,539**	**135,700**

Source: Based on unpublished (classified) Nationwide 14th Decennial Census Survey, 2001

In 23 August 2001, in a press conference, Planning Advisor, Mr M. Hafiz Uddin Khan, of the then caretaker government released "Census 2001: A Primary Report" (The Daily *Janakantha*, 24-Aug-2001, Dhaka). The result is given in Table 4-3.

Table 4-3: At a glance: Summary National data from Primary Census Report 2001 of Bangladesh

Item	**Result**
The Census Moment (Zero Hours)	January 23, 2001 at 0.00am
Total Enumerated Population	123,151,246
The Adjusted Population	129,247,233
Average National Enumeration Error (in per cent)*	4.95
Annual Population Growth rate	1.48
Population Increased in the inter-censual period (1991-2001)	16,836,254
Population Density per square kilometres	834
Sex Ratio	103.80 males per 100 females
Household Size (persons)	4.8
Urban population (in percent)	23.39

(c) Rapid Population Growth

As shown in Figure 4-3, the density of population per km^2, of Savar has increased dramatically since 1991. In 1951, the density was only 355 per km^2 while in 2001 it has reached more than six times that at 2,238 per km^2 as shown in the graph. The lower parts of bar chart show the national density and the upper stacks show the immigrant population in Savar upazila if we consider that the natural population growth (based on birth and death rate only i.e. excluding migration issues) in Savar was always equal to the national level. As per the Bangladesh standard it would have had (284 km^2 x 834 =) 237,381 people in 2001. At the standard of Dhaka District (where Savar upazila itself is also included), the population figure would be (284.63 x 5859 =) 1,667,647. In all probability the Savar figure will rise to the Dhaka standard, which means about 3 times higher than the current density. This might happen in a few decades only. Further, the real population density in the area of Dhaka City Corporation is much higher (at least 5 times) than that of Dhaka District. So, the future of Savar is unimaginably complex and alarming! Over the last 7 censuses, the rate of population growth has increased 6 fold. This reflects, in every decade, a doubling of population. So to catch up with the current Dhaka density of population, it will take less than three decades. More importantly, only two decades ago, Dhaka District had a similar population density to that current now in Savar upazila. Not all parts of the upazila will be affected evenly by the increase in population density and we need to find out which unions are favourable for rapid growth rates. For the planners and decision makers, this sort of knowledge is important to devise the necessary strategy for its sustainable development and progress.

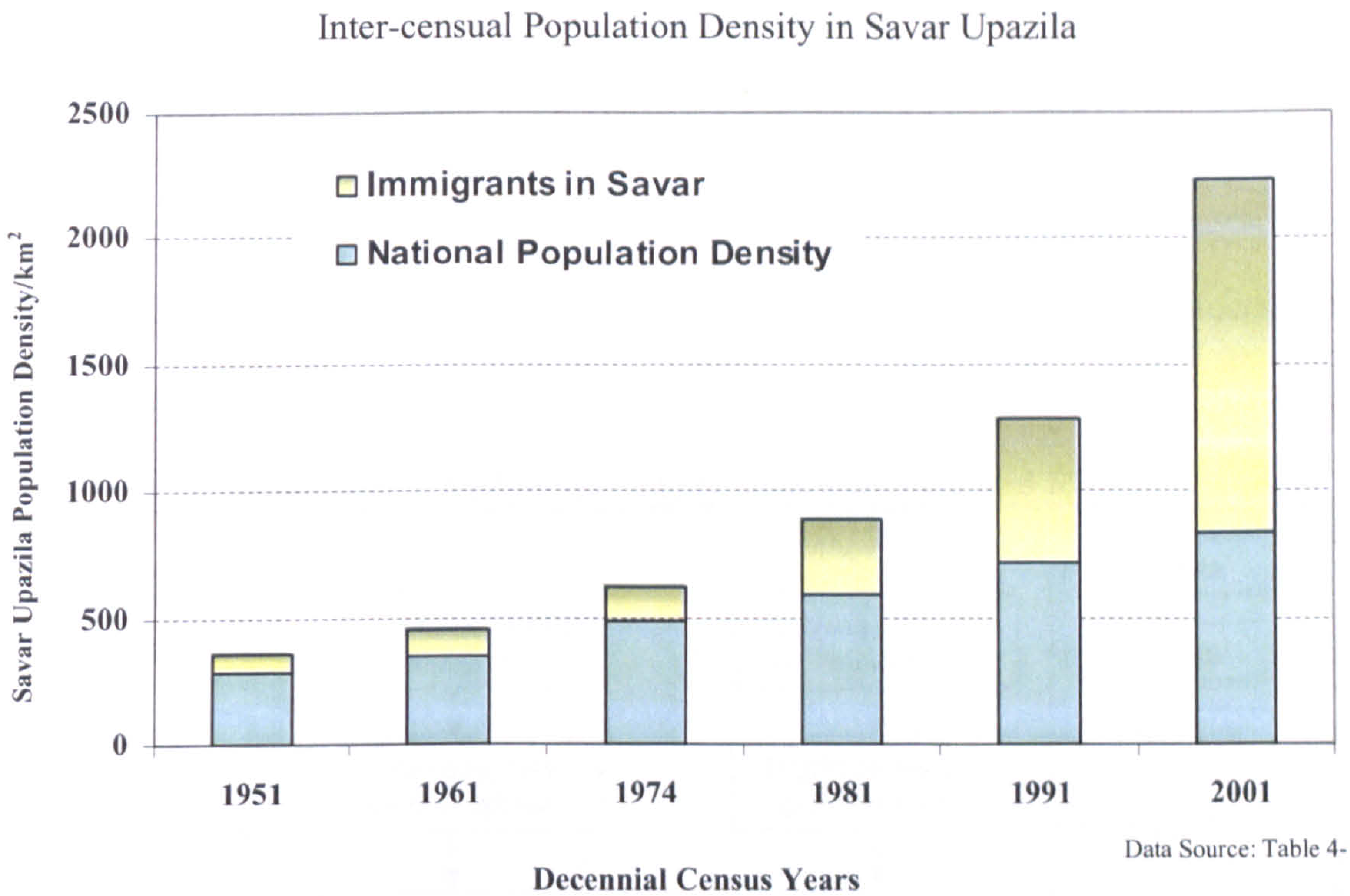


Figure 4-3: Population density of Savar upazila in comparison with the national average. The lower stack records local people while the upper stack shows net immigrants to the upazila.

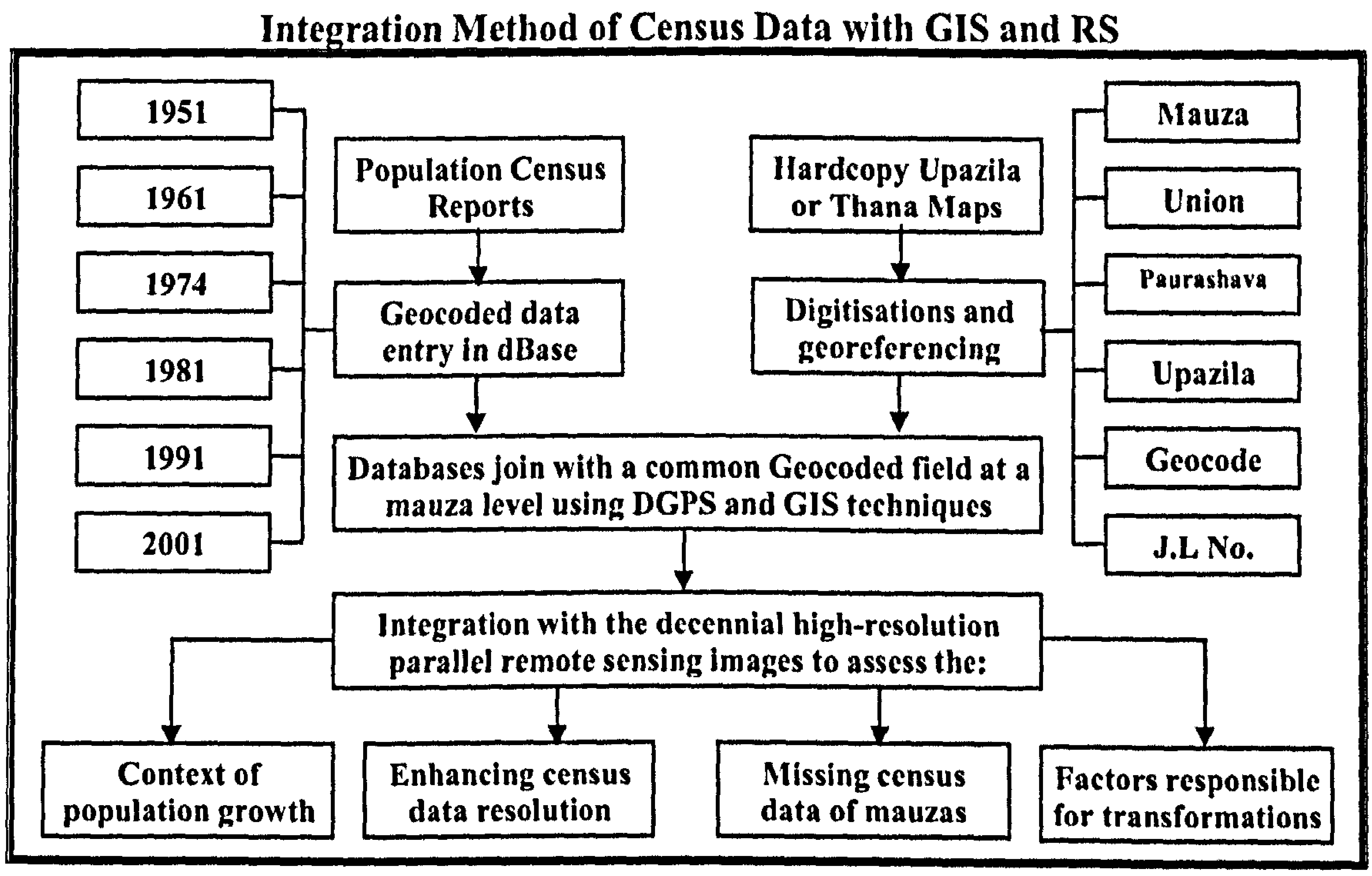
4.2.0. Methodology

This chapter is based on both remote sensing and census data and GIS has played a significant role to make them understandable. The following integration, enhancing and interpretation methods are important among others.

(a) Integrating Techniques

The lowest census block (or enumeration zone) in Bangladesh is known as a mauza, which encompasses a defined geographic jurisdiction. Most importantly, the same jurisdiction has been maintained over the last 14 population censuses at each decennial scale since 1870s. This is most advantageous for carrying out research. In case of Savar, the average size of a mauza is about one square kilometre. So the total population is changing over time but the jurisdiction area is constant. As my research is spread over the last half century (the post colonial period), I have used the census data since 1951.

I have collected all the relevant reports of censuses and coordinated these databases into a GIS format. The following chart (Figure 4-4) gives the details, of how the process has been carried out to integrate these two fields.



Source: Adopted by author, 2002

Figure 4-4: A generalised methods of integrating decennial census databases (1951-2001) and maps from hardcopy to soft format with necessary attributes. The method is used here to understand the context and quality of the census data using remotely sensed images from early 1950s to 2000s. Calibration and processing techniques of remotely sensed data have been discussed in the relevant chapter.

(b) Steps of Integration

Figure 4-4 shows the generalised picture of how to integrate census data with the parallel remote sensing photos. I have collected the relevant hard copy of maps of Savar upazila so that geocoded information can be tagged together in GIS format. The following steps were followed in this regard.

Step 1. All the census reports were collected from the different sources and the data entered in DBF format. The databases covered 1951 to 2001. In 1971, Bangladesh was at war with Pakistan, so it was not possible to collect census data at the time, but after an improving field situation in 1974, the census data was collected.

Step 2. I used a LGED upazila base map for integrating census data at mauza level. The quality of the LGED map was very poor and a lot of mauzas were missing (see Table 4-13) so earlier maps were used to correct the LGED map. I then digitised the map using DLRS and LGED's J.L (jurisdiction list number for the individual mauza and other administrative territories) to identify any location. After digitisation, Lambert Conformal Conic Projection parameters were used to transform the coverage to real world coordinate systems. The coverage also contains a different administrative hierarchy of boundaries such as mauza, paurashava, Union, upazila, district, and Dhaka city corporation boundaries.

Step 3. On the basis of JL and Geocoded data, both of the coverage-dbf datasets were joined together. Now the spatial distribution of census data could be seen from the tabular form.

Step 4. When all of the census and mauza databases were ready, they were integrated with the Aerial Photos, Satellite Images and CORONA films using the remote sensing techniques, as discussed in the previous chapter.

Step 5. Then different overlapping methods were employed to assess the quality of the census data with the help of image interpretation techniques.

(c) Enhancing Census Data Resolution: From Mauza to Sub-mauza

I propose a new method to enhance the resolution of population census data. The method to identify settlements from the air/space and correlates them with the census databases. The following steps can be followed in this regard:

Step 1. Using sub-metre accuracy, DGPS data has been used to calibrate image data using the same projection used for upazila map at mauza level;

Step 2. Classify the settlements according to the interpretation key as mentioned in the previous chapter;

Step 3. Digitise settlement zones from the high resolution images using GIS software (e.g. settlement 2001);

Step 4. Entry of 2001 census data in GIS format at mauza level (e.g. census 2001);

Step 5. Intersect both the settlement and census coverages;

Step 6. A new database and coverage was created where the part of the mauza without settlements was deleted.

Step 7. A new census database was required with new fields created at each sub-mauza level. A new density of population was calculated, which would be higher than in the original density database;

Step 8. The portion of settlements which overlapped with roads were subtracted according to the buffer of each road type (for example for National HW = 25 metres, restricted road = 15 metres, pucca road = 8, semi-pucca road = 6 metres and Katcha road = 4 metres). So, the sizes of the settlements have been reduced again.

Step 9. Now the actual settlements were filtered. After this I intersected the population 2001 coverage with the sieved settlements.

Step 10. In the intersected coverage, I added a few columns to calculate the population in each settlement based on the census 2001 data. Here, all settlements of each mauza have been assumed to have equal density of population.

Population density has also been calculated per km^2 in order to map density of population.

This enhancement technique is the first Bangladeshi attempt to convert from the mauza census boundary to the level of village boundary. Mauzas in Bangladesh can be populated, unpopulated or partially populated but a village must be populated. A mauza boundary is fixed by its jurisdiction but the village boundary changes all of the time naturally. Other than containing settlements, a mauza may include agricultural land, fallow lands, water bodies and so on.

(d) Settlements Interpretation Techniques

Settlements are the key land features which contain census data. In this chapter, the settlements are the most important concern for the satellite and air photo databases while for the census reports, the density of population is the most important phenomenon to link them. Here, for in-depth database calculations I have focused on the following mapping and image processing methods:

(1) Identify certain territories from a group of settlements based on image interpretation techniques;

(2) Drawing boundaries on the periphery of each settlement cluster;

(3) Calculating the area in km^2 for each settlements and each relevant year;

(4) Merging and intersecting the databases at mauza and Union level;

(5) Adding census attributes to each settlement group to visualise the density of population at the mauza level;

(6) Identify the areas which are not populated so that the areas can be separated from the census databases;

(7) To follow the techniques for the each census year with the corresponding satellite images to develop a database for Spatio-temporal Transformation Index.

(e) Geo-coded Data versus Geo-referenced Data

In most developing nations the population census databases are mainly geocoded or place-name referenced. It is often very difficult to integrate these databases for GIS analysis as there is a serious lack of geo-references or precise national grids for the EDs (enumeration districts), such as the mauza boundaries which are widely used in South Asia. With the help of GIS coverage of upazila maps and by integrating high resolution remote sensing images, the geo-coded census data can be transformed into geo-referenced census data. In this chapter, census data enhancing methods are also applicable for the same purpose, because against the settlement locations, x and y grid coordinates are generating as metadata of the concerned settlements. I used and developed the following method for the 'Arc Avenue' programming language, to get geo-referenced information in LCC and BTM projections.

Script 4-1: Defining Geo-projection for the ArcView project.

```
' Create a CoordSys object and get its list of projections
c = CoordSys.Make
c.SetName("Shahed_Rashid's Custom Projections")
projections = c.GetProjections

' Create a projection
r = Rect.Make(103@"-56".AsNumber,164@"-7".AsNumber)
projection1 = Lambert.Make(r)
projection1.SetDescription("Savar Upazilaas LCC")
projection1.SetCentralMeridian(90)
projection1.SetReferenceLatitude(26)
projection1.SetUpperStandardParallel(28.8)
projection1.SetLowerStandardParallel(23.15)
projection1.SetFalseEasting(2743185.699)
projection1.SetFalseNorthing(914395.233)

projection1.SetSpheroid(#SPHEROID_EVEREST)

' Create another projection
projection2 = TmMerc.Make(r)
projection2.SetDescription("Savar Upazila as BTM")
projection2.SetCentralMeridian(90)
projection2.SetReferenceLatitude(0)
projection2.SetScale(0.99960)
projection2.SetFalseEasting(500000)
projection2.SetFalseNorthing(-2000000)
projection2.SetSpheroid(#SPHEROID_EVEREST)

' Add the new projections to the CoordSys projections
projections.Add(projection1)
projections.Add(projection2)

' Create a default.prj file and add the CoordSys object
defprj = ODB.Make("$HOME/default.prj".AsFilename)
defprj.Add(c)
defprj.Commit
```

Script 4-1 is vital to carry out any projection parameters used in Bangladesh as well as specifically for this research. The advantage of this method is that we can switch to any projection easily from those widely used to methods current in Bangladesh. It also helps to build up geo-referenced values for a geocoded database.

(f) Identifying Errors in the Existing Maps

In carrying out this research, I realised that the spatial databases in Bangladesh are in a very poor condition. Even the database produced for military purposes is not accurate. Before starting this work, my assumption regarding map information was that "an inaccurate map is better than no map", but now I believe that "No map is far better than misguiding existing maps". The main reasons for this are:

(1) To identify any mistake(s) in a map is more complicated than developing new databases or digital version of maps;

(2) If the data is present, government or private organisations do not show any interest in building new data and just buy the existing databases. But when any projects start depending on these databases, the reality comes onto surface. They cannot use these maps effectively and there may be no money for modifications;

(3) Some organisations (e.g. LGED) use the defective databases, so any plan or development initiatives based on this information are unrealistic and the negative consequence is obvious. For example, if the government wants to build a new school based on wrong settlement maps (Figure 4-5), the benefit to local pupils is jeopardised.

In Figure 4-5 the all red colours are produced by the author from the present research, and the blue colour areas are from LGED database. Three types of scenario can be mentioned:

1. Both colours have some common locations of settlements, so both of them to an extent are correct or true;
2. There are some places, mainly on the chala land areas, where a lot of red colour settlements areas are located but now shown in LGED maps;

3. Some of the places are shown in the LGED maps, mainly on the northern low land areas, where there is no trace of settlements on the ground and these areas go under deep floods during rainy season.

4.3.0. Results and Discussion

4.3.1. Analysis of Data and Images

From the methodology section, we can see that two major types of data have been collected to carry out of this research. All of the GIS and census data have been developed from hard copies, which was an enormous task and very time consuming. Bangladesh does not have good digital data archives like the UK. For a UK researcher, topographic maps can be downloaded using the Digimap system. The researcher here has access to these databases and they take the availability of these data for granted. That is not the situation in developing countries. In Bangladesh it will take many decades to reach such a quality and to make data available to the public. So to build databases for any research project in Bangladesh is very time consuming and complex. To work in a very poor country to obtain raw databases is also a problematic. If a database is available, then the quality of the data is still a big question.

The population census data in Bangladesh is based on mauza maps. These vary:

- Non-uniform spatial distribution of population in the mauza;
- Uniform spatial distribution population;
- Unpopulated mauza, with no sign of settlement;
- A gradual and temporal change and direction of expansion within a mauza over time;
- Contextual factors like any threat of river bank erosion or impact of a land acquisition in a mauza;
- Land types or physiography of a mauza.

Figure 4-5: Error Mapping of the LGED map with the help of digital coverage developed from the IRS-1D images and the field investigation. Solid red settlements are not shown on the LGED map and solid blue areas are not available on the land and misleading, I verified this error during the field investigation in 2001. Red and Blue mixed colours are the intersected areas, where both LGED and my map have identified the same regions.

The census data tables do not give detailed information on spatial patterns. Only remote sensing images can give the satisfactory answers to the questions: Where? How? Or Why? The reason for the distribution of population is usually ignored due to the unavailability of parallel image data and the lack of proper technological (e.g. hardware, software and humanware) support. The factors and context of population growth and spatial distribution are therefore neglected in Bangladesh. The spatio-temporal situations have changed rapidly since 1951, and the reasons or factors responsible for the spatio-temporal distributions have also varied from census to census, so this neglect is regrettable.

In Savar population data at mauza level is available from 1951 at a decadal interval. This reveals that at present the total population of Savar is distributed on only 12 percent of the land.

Limitations of census data in the context of the current research:

1. It does not give the context but has the population database.
2. There is no way to analyse why an area has more or less that an average growth rate.
3. The quality of the census data is open to open to question because of some missing villages.
4. It does not have geo-coordinates but has geo-codes.

(a) Summary Database Development from Censuses

In this research, databases have been created from the various census reports and documented in a GIS framework. The lowest level of information base was the mauza. A summary is presented at Union level in Table 4-4. This Union level database is very important to understand the dynamics of land cover changes of Savar upazila. The Union is the lowest unit of the electoral system in Bangladesh, so any change at this level is very important for the planners and policy makers. Table 4-4 is the primary database for further analysis. The population data come from the census reports, but the area data in km^2 have been calculated using GIS techniques after the digitisation of hardcopy map data.

Table 4-2 summaries population census data at Union level calculated from the mauza data for further analysis. The population of Paurashava (including Savar Union) has been in the leading position since 1981. Before that Simulia and Bhakurta unions were ahead. Total figure of population is very important because the locally elected *Union Parishad* (local council) gets per capita funding from the government.

Without knowing the density of population, it is very difficult to assess the overall situation at the field level, and this is essential for the planner and policymaker to understand the complex pattern of settlements and infrastructures and help to find development parameters for any administrative unit. The table illustrates the facts about the density of population. Here, Bhakurta had the highest population density until 1960s. Then Kaundia took the control of the density rank. After that since the early 1980s, Savar Paurashava had the highest population density. The least populated unions are Biralia and Yearpur. In total Savar upazila had 101,000 people in 1951 but in 2001, the Paurashava itself got much more than that.

Table 4-4 shows the actual population of the census years since 1951. With the total population of the upazila placed in the end row. The traditional method of calculating population density using the total area and population data, for Union level population density is shown per km^2 in Table 4-5. In the last row, the total population density for the overall upazila is calculated. But in Table 4-6, the share of population total in percentages is measured. As a result, total figure in the last row is 100 for each census year. The population related information is from 1951 to 2001, and the relative picture of the each Union can be compared easily. The information provided in Tables 5-5 and 5-6 is important for the current chapter to understand the Union level scenarios and later for the explanation of the context and cause of the population growth. However, the tables raise more questions than they answer. For example, why has population fluctuated over time at Union level over the last half century? Why do some unions attract more people than others? Why are the population pull factors not stable over time? Why in certain areas are population concentrations very high? Within a Union, are settlements expanding homogenously. If not, why not? Do the statistics show the true reflection of population growth for a Union? And there are many other questions.

(b) Settlements Mapping from RS images

Under the database development objective of this chapter, I mapped several basic land features highly relevant for the population growth in the upazila. The maps have not been digitised for a single year. All 6 inter-censual year images have been converted. Particularly, where varieties of remotely sensed photos were used, special interpretation skill was required for the transformation, because aerial photos, spy films and satellite image were all used. As examples, the two important settlement maps in Figures 4-6 and 4-7 have been transformed into final shape. These maps are highly valuable for historical researchers and the authorities relevant to planning and development. They give a glimpse how an old and a very rural settlement pattern has been gradually changing and has adjusted to the current context of the complex development and infrastructural scenarios of the upazila. From these maps, in the next chapter, I will mention about the variety of settlement contexts and shapes by linking with the other land features and land types.

Table 4-4: Decennial Population Census Database at Union level during 1951-2001

Union	Area (km^2)	Pop^n '51	Pop^n '61	Pop^n '74	Pop^n '81	Pop^n '91	Pop^n '01
Kaundia	7.777711	4,283	6,543	7,710	11,975	14,414	20,464
Savar	10.761744	2,105	3,267	81	4,414	7,860	16,957
Amin Bazaar	10.985479	6,287	7,059	9,329	13,499	26,129	33,140
Paurashava	16.722107	7,631	9,955	13,131	32,157	68,952	132,435
Banagram	17.283998	7,050	9,210	10,135	16,697	20,840	25,200
Bhakurta	20.346887	14,810	16,776	19,843	26,260	33,113	38,025
Tetuljhora	20.647069	6,549	10,053	13,582	20,870	28,592	45,137
Ashulia	26.304358	7,377	9,112	10,261	17,448	21,164	43,804
Yearpur	27.442332	6,543	8,110	1,927	14,055	16,422	27,044
Pathalia	28.450085	7,180	10,123	11,091	26,255	39,555	69,656
Biralia	29.660584	7,530	9,874	11,801	15,521	18,478	24,917
Dhamsona	33.130425	8,860	12,084	7,819	22,672	33,626	98,764
Simulia	35.120264	15,100	17,908	14,719	30,202	36,107	59,966
Upazila Total	*284.63 km^2*	*101,305*	*130,074*	*131,429*	*252,025*	*365,252*	*635,509*
Density/ km^2		*363/ km^2*	*464/ km^2*	*469/ km^2*	*892/ km^2*	*1,290/ km^2*	*2,240/ km^2*

Note: Pop^n indicates population

Table 4-5: Traditional way of calculating Population Density per km^2 at Union level of Savar Upazila

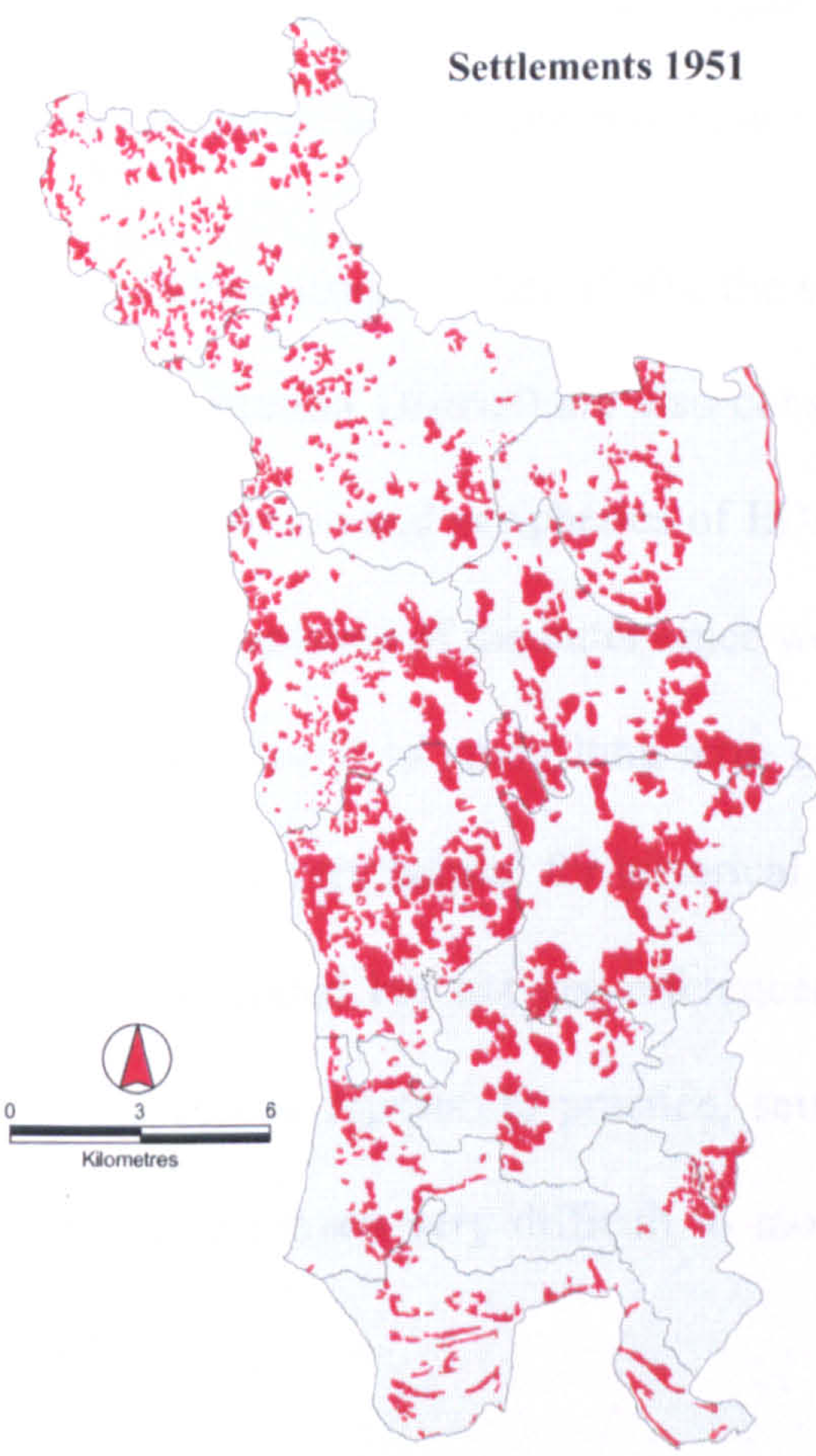
Union	Area Km^2	c1951	c1961	c1974	c1981	c1991	c2001
Kaundia	8	551	841	991	1540	1853	2631
Savar	11	196	304	8	410	730	1576
Amin Bazar	11	572	643	849	1229	2379	3017
Paurashava	17	456	595	785	1923	4123	7920
Banagram	17	408	533	586	966	1206	1458
Bhakurta	20	728	824	975	1291	1627	1869
Tetuljhora	21	317	487	658	1011	1385	2186
Ashulia	26	280	346	390	663	805	1665
Yearpur	27	238	296	70	512	598	985
Pathalia	28	252	356	390	923	1390	2448
Biralia	30	254	333	398	523	623	840
Dhamsona	33	267	365	236	684	1015	2981
Simulia	35	430	510	419	860	1028	1707
Density/km^2	285	356	457	462	885	1283	2233

Note: here, c1951 means Population Density of Census 1951 and so on per km^2.

Table 4-6: Population shared in percentage by the each Union of Savar Upazila

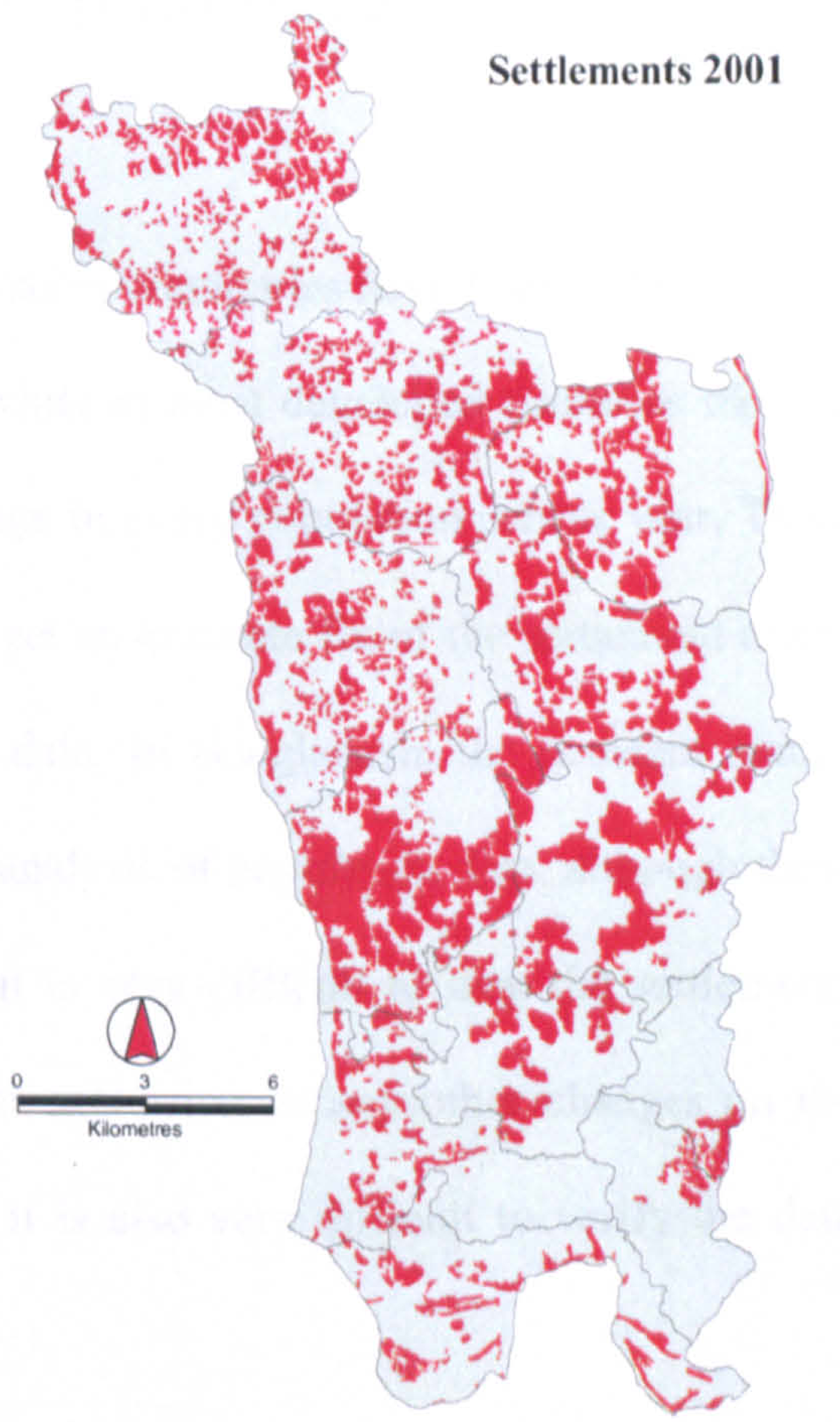
Union	Area %	c1951 %	c1961 %	c1974 %	c1981 %	c1991 %	c2001 %
Kaundia	2.73	4.23	5.03	5.87	4.75	3.95	3.22
Savar	3.78	2.08	2.51	0.06	1.75	2.15	2.67
Amin Bazaar	3.86	6.21	5.43	7.10	5.36	7.15	5.21
Paurashava	5.87	7.53	7.65	9.99	12.76	18.88	20.84
Banagram	6.07	6.96	7.08	7.71	6.63	5.71	3.97
Bhakurta	7.15	14.62	12.90	15.10	10.42	9.07	5.98
Tetuljhora	7.25	6.46	7.73	10.33	8.28	7.83	7.10
Ashulia	9.24	7.28	7.01	7.81	6.92	5.79	6.89
Yearpur	9.64	6.46	6.23	1.47	5.58	4.50	4.26
Pathalia	10.00	7.09	7.78	8.44	10.42	10.83	10.96
Biralia	10.42	7.43	7.59	8.98	6.16	5.06	3.92
Dhamsona	11.64	8.75	9.29	5.95	9.00	9.21	15.54
Simulia	12.34	14.91	13.77	11.20	11.98	9.89	9.44
Percent Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

In the figures in this chapter, all unions are shown and their relevant databases are discussed in the next section. All Union base descriptions and the discussion of factors responsible for the changes will be done with the help of these maps. As examples, in Figures 4-6 and 4-7, the periphery of the settlements have been identified and digitised from the remotely sensed imagery.



Source: classified from Aerial Photos of 1953

Figure 4-6: Settlement distribution of Savar upazila at Union level during the early 1950s.



Source: classified from IRS-1D of 2000

Figure 4-7: Settlement distribution of Savar upazila at Union level during the early 2000s.

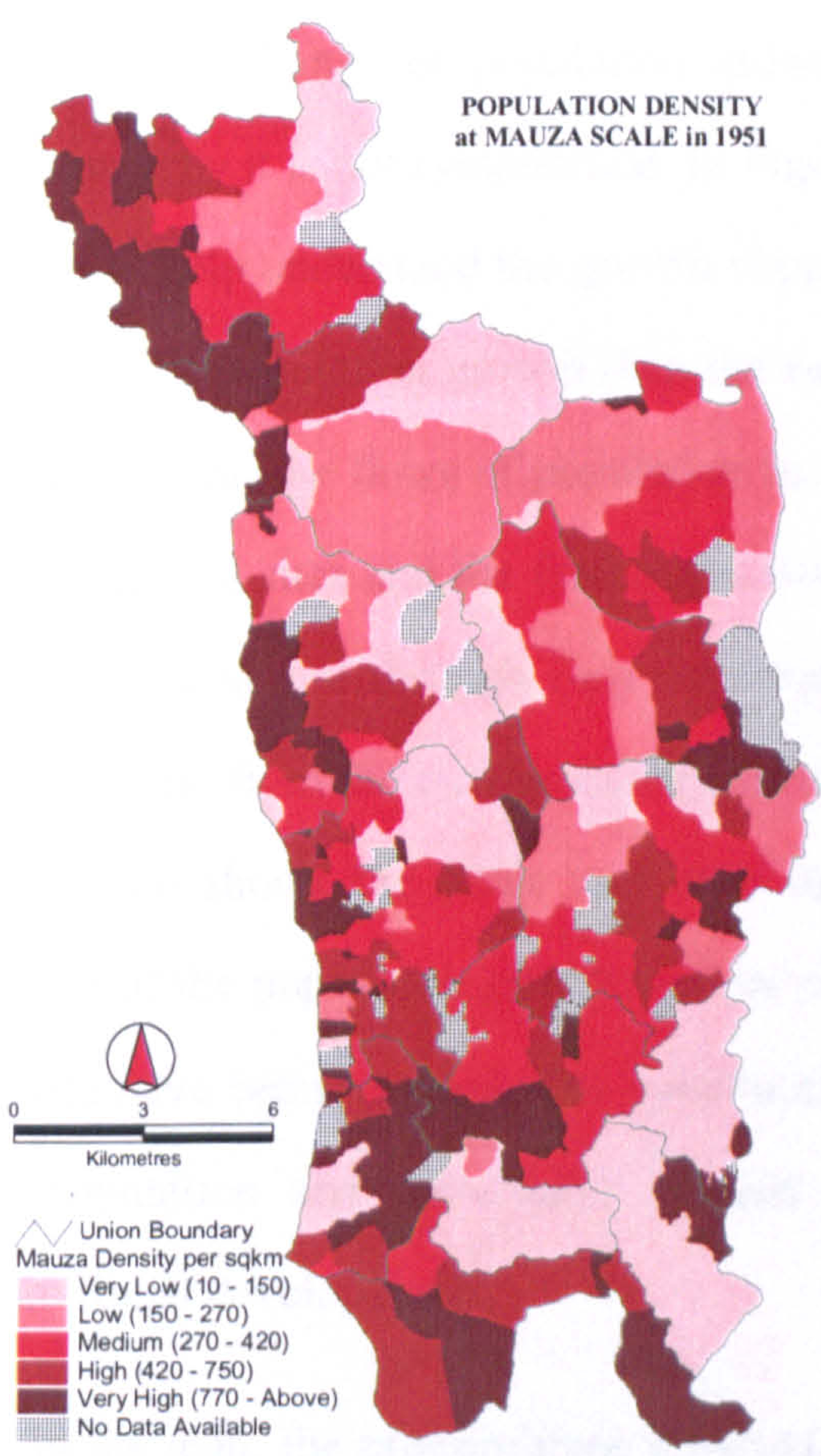
(c) Combining Census and RS Databases

Population density based on digitised settlement areas from the remotely sensed images is one of the most important examples in this chapter. The term used for this sort of mapping is 'enhancing census data using remote sensing techniques'. The traditional way of showing population density using the administrative unit at mauza level and population census data is very common in Bangladesh. In this perspective, enhancing the resolution with the help of Figure 4-9 is a very important beginning for new spatial mapping techniques for Bangladesh and its surrounding countries. The general map is a mauza scale population density map (Figure 4-8) and the enhanced density map (Figure 4-9) is a sub-mauza scale population map. More than 85 percent of land has been filtered and isolated where no settlements existed in 1951.

In Bangladesh, since the late 1880s, the same mauza boundaries have been followed. The EDs (Enumeration District) are also constant while in most developed countries like the UK, the definition and peripheries of EDs change in every population census year. There are some advantages of the latter since we can get an accurate fix of the settlement areas, but the problem is to study long-term census data. In Bangladesh, the constant mauza boundaries are very helpful for historical trend analysis of population data, although these data are geocoded but not geo-referenced, so it is very difficult to map the settlements from the census reports. In practice, settlement expansion or any other changes on the ground have proved very difficult to monitor, it is also very difficult to verify the data quality.

In this complex milieu, high resolution satellite images or aerial photos can play a very significant role. The following example of the 1951 enhanced census map (Figures 4-8, 4-9) gives a very practical solution for the field problems. These data can be used for any planning, or development study, environmental risk assessment and so forth. Moreover, the problem of geo-coded and geo-referenced data can be overcome, as the map now has both information bases. Due to lack of the geo-referenced co-ordinates, the spatial context of census data has been little used at the local level in Bangladesh. From now on they will carry a very special significance for the relevant studies.

Traditional ways of mapping population density at mauza level were based on census data using the upazila administrative base map (Figure 4-8). A geo-statistical 'equal area' classification technique has been adopted here for both maps, which were normalised by the area of concerned mauza. The whole of the land has been classified here. Five categories are illustrated from very low to very high density per km^2. This map cannot show settlement positions directly, so from the planning and development aspect, this is a blind map. We can only imagine the density of that small geo-coded administrative unit.



Source: classified from Census of 1951

Figure 4-8: Traditional ways of mapping population density at mauza level.

Source: reclassified based on Aerial Photo of 1953

Figure 4-9: Enhanced ways of mapping population density at sub-mauza level.

The traditional population density map has been sieved using settlement locations based on remotely sensed images and 'interpretation techniques' and the equal area classification method as mentioned above (Figure 4-9). Here only inhabited areas (12% of the total area of the upazila) are shown at the sub-mauza (village and/or para) level, which will help the planners or policy makers to adopt practical solutions regarding development and environmental issues. Here the density of population is far higher than in Figure 4-8. This is much more realistic. The map helps to reduce more than an 88 percent if error in terms of land. This map also shows the exact settlement distribution and its pattern.

(d) Mapping the Complexities of the Context

Any uneven change or population growth must have a contextual background, which explains why it is not symmetrical. In Figure 4-10, the population growth of the upazila is shown to help understand the growth situation at Union level. Most of the western unions have higher population growth than the eastern unions. To understand the reasons behind the disparities, the flows of population in their respective years are given. The significant infrastructural sites and the flow paths have been visualised based on decennial remotely sensed images and through field investigations. As shown in Figure 4-11, most of the people came from the outside Savar and now the majority of the population are migrants. The figure shows the paths and their direction into this territory. Here the historical context of the population growth and the infrastructural context of the in-migration in the upazila have been mapped. The construction of new roads has meant new flow paths of the population and these have created a favourable environment for industrial and institutional developments.

So, in the map, the proportionate population density of Savar upazila has been illustrated at Union level. The six bars from left to right reflect the population density from 1951 to 2001. Here the map shows that Savar (including the Paurashava), Pathalia and Dhamsona unions have pooled a significant amount of population over time. These three unions have three different factors in attracting population. For Savar (including the Paurashava) Union, all of the upazila HQs and the municipality (since 1996) are concentrated here. In 1970s, the establishment of a government University was the pull factor in Pathalia Union. In the 1990s, Dhamsona Union embraced one of the biggest export-processing zones, which attracted a significant amount of population. All of the eastern unions have had a steady growth rate, e.g. Biralia Union, but exceptionally, in the south and north respectively, Bhakurta and Simulia unions have lost their importance as they contributed only fertile land for agricultural activities. These maps helped me to make a decision about what area would be interesting for remote sensing change detection research.

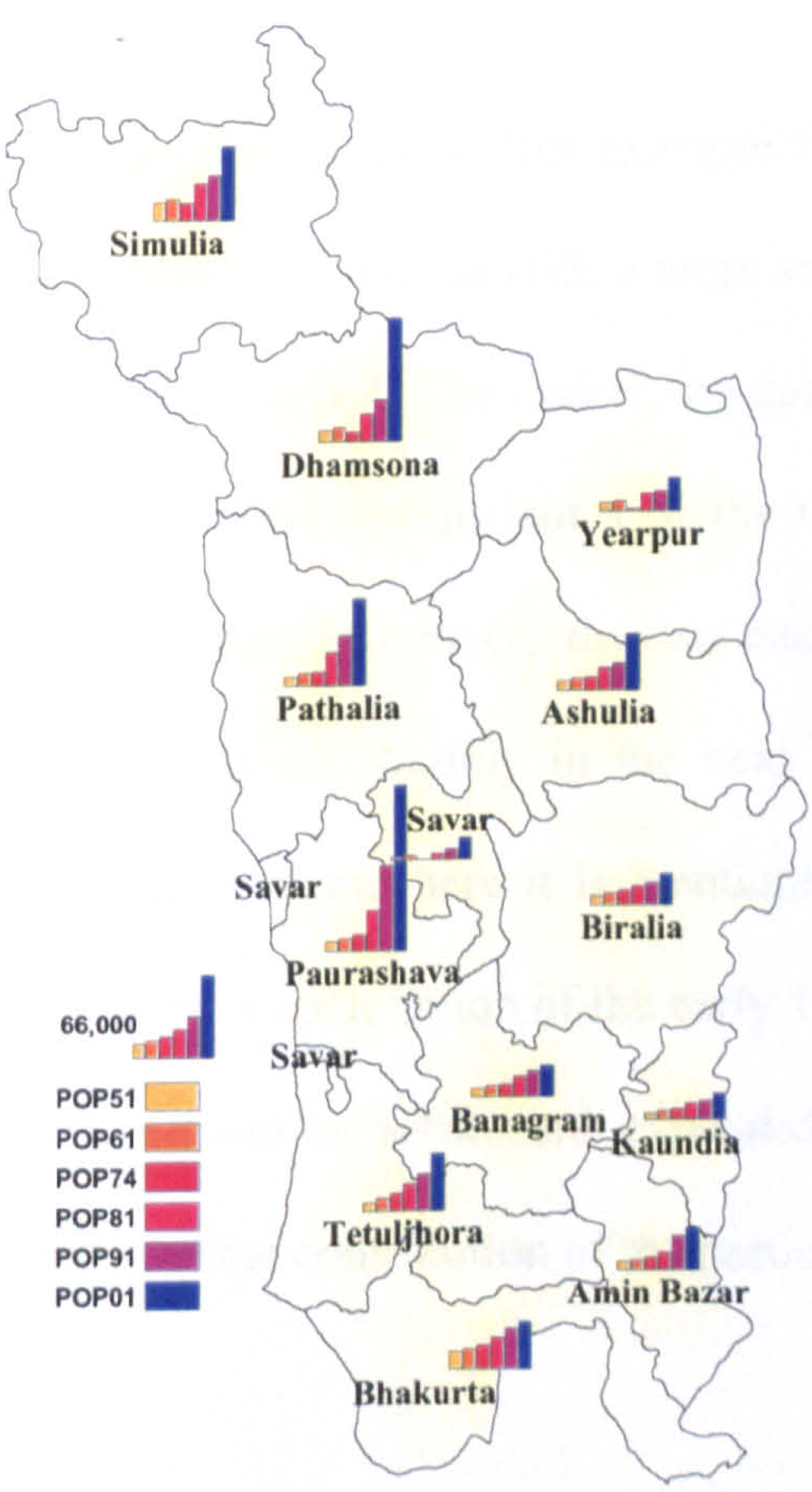


Figure 4-10: Comparisons of population growth at Union level.

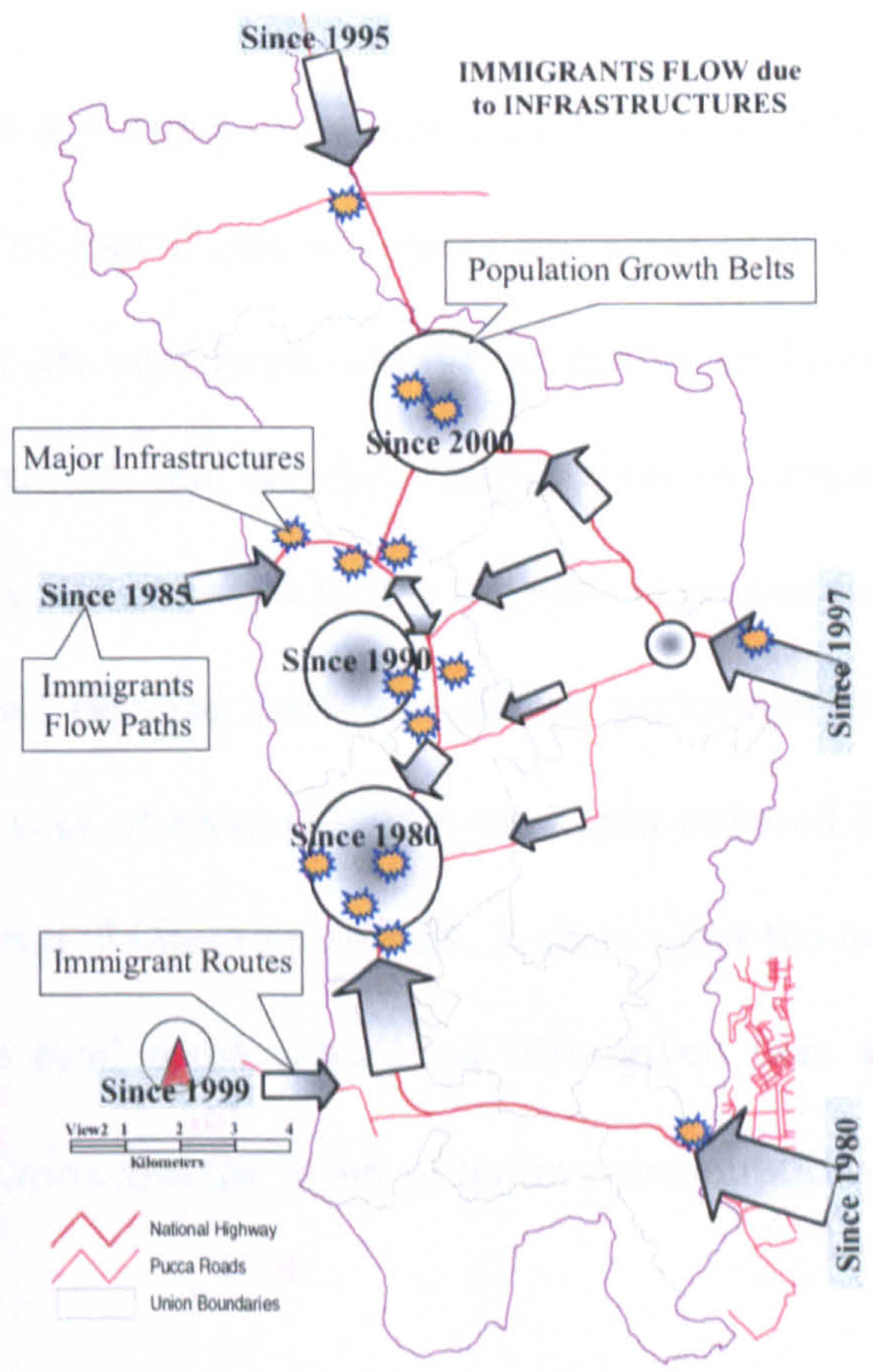


Figure 4-11: Direction of Population influx towards the major locations of infrastructures.

(e) Overlapping the Responsible Factors

I used overlapping techniques to understand the underlying complexities of the land transformation systems. For example, in Figure 4-12, the *pucca* roads, including the highways which formed route ways for in-migrants and the location of major development centres, are combined to see the influence of these phenomena. The databases are all taken of 2001 and census data have been integrated here at sub-mauza level. This example is comparable with Figure 4-19 of 1951 to gauge what change has happened over half a century. The context and factors are completely different for the two figures.

(f) Database Developments from RS Images

The maps shown above (for example Figures 4-6 and 4-7) are not only for cartographic and display purposes. In GIS, a huge amount of spatial data is created and some of this is shown in Table 4-7. The underlying databases are very important for the further analyses. These databases are attributes of the GIS analysis and for the interpretation of remote sensing images. Moreover, the data can be used as metadata for the population census and raster data bases. Mainly in the next chapter, detailed analyses will be performed for further analysis but here it is mentioned by way of example. The total area covered as settlements in each Union of the early 1950s and 2000s is given here. It shows that the net area increased as settlement expanded. The total areas shared are also given here to understand the contribution of the particular Union and the zones of major concentrations.

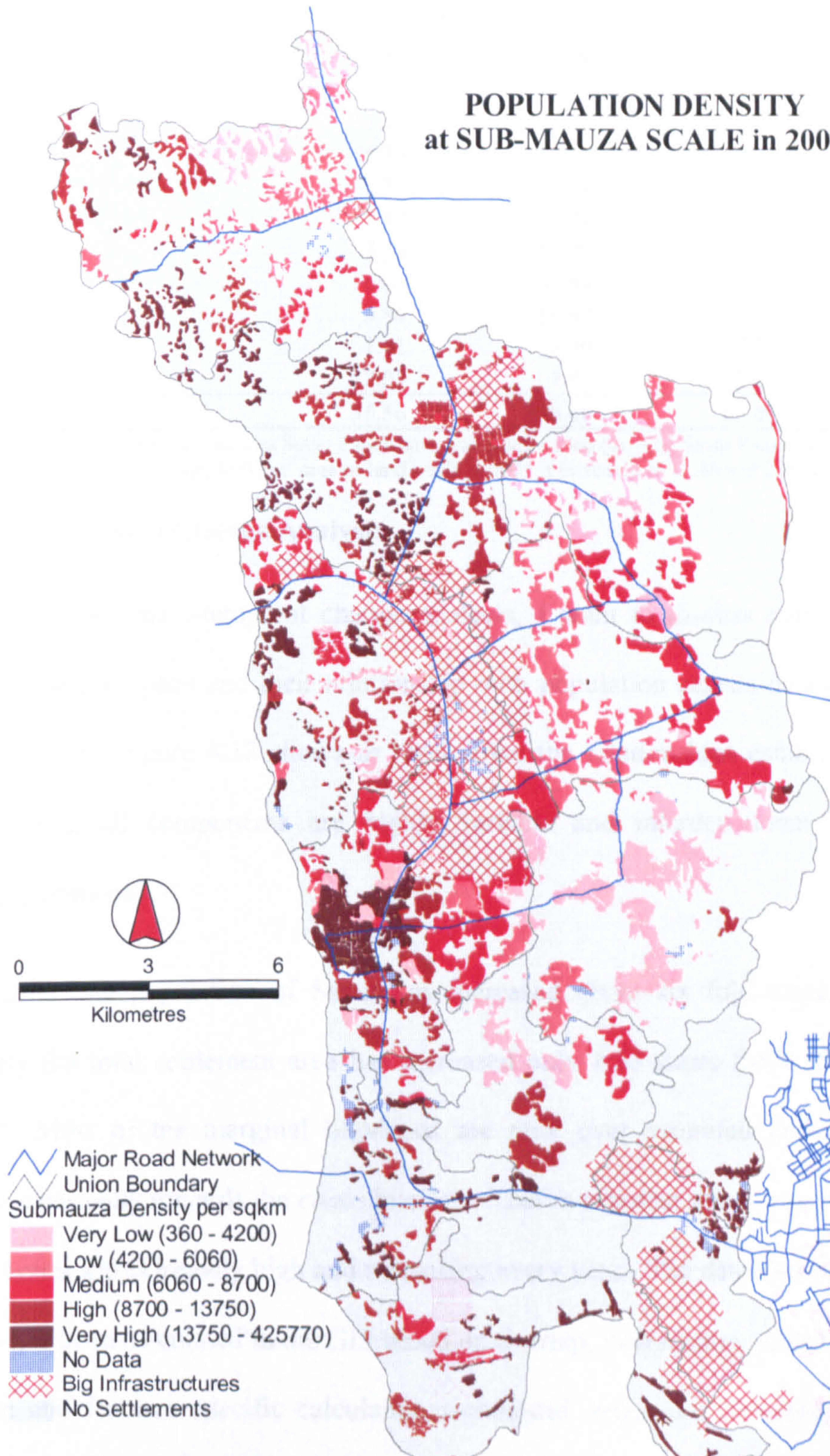


Figure 4-12: Enhanced population density of 2001 at sub-mauza scale overlapped on the settlements.

Table 4-7: Area allocated for Settlements in the early 1950s and 2000s

Union name	km^2 51	% 51	km^2 01	% 01
Amin Bazaar	0.34	0.96	0.46	0.71
Ashulia	4.26	11.98	7.38	11.34
Banagram	2.21	6.21	3.37	5.18
Bhakurta	1.46	4.11	2.52	3.88
Biralia	5.29	14.87	6.96	10.69
Dhamsona	2.77	7.78	7.39	11.35
Kaundia	0.43	1.22	0.58	0.89
Pathalia	4.25	11.95	5.72	8.78
Savar*	6.64	18.68	15.86	24.37
Simulia	3.86	10.87	6.85	10.52
Tetuljhora	1.41	3.96	2.35	3.61
Yearpur	2.63	7.41	5.65	8.68
Upazila	35.56	100.00	65.09	100.00

*Note: Here Savar includes Savar Paurashava and Savar Union (in 1951 Savar Paurashava had 5.75 km^2 and Savar Union had 0.90 km^2 area of land while in 2001 it increased to 13.46 and 2.40 km^2 respectively.

4.3.2. Spatio-Censual Change Analysis

Before staring the spatio-temporal change analysis, I want to discuss some schematic linkage in time and space and their relationship with population census data and remote sensing imageries. Figure 4-13 shows in ideal terms the relationships established in the research, where all components are highly variable and interdependent on rapidly changing phenomena.

As an upazila, the population of Savar has increased about six fold since 1951, but interestingly the total settlement area has increased only 1.83 times from 35.56 km^2 to 65.09 km^2. Most of the marginal highlands are now over saturated and the current expansion is basically towards the *chala* interiors. That means that the compactness of the populated zones are extremely high and increasing every year. The database shown in the discussion has been calculated in the GIS based on overlap, intersection, dissolve, clip and spatial join and features specific calculation techniques under geo-processing modules. These databases have been developed from high resolution images and census attributes.

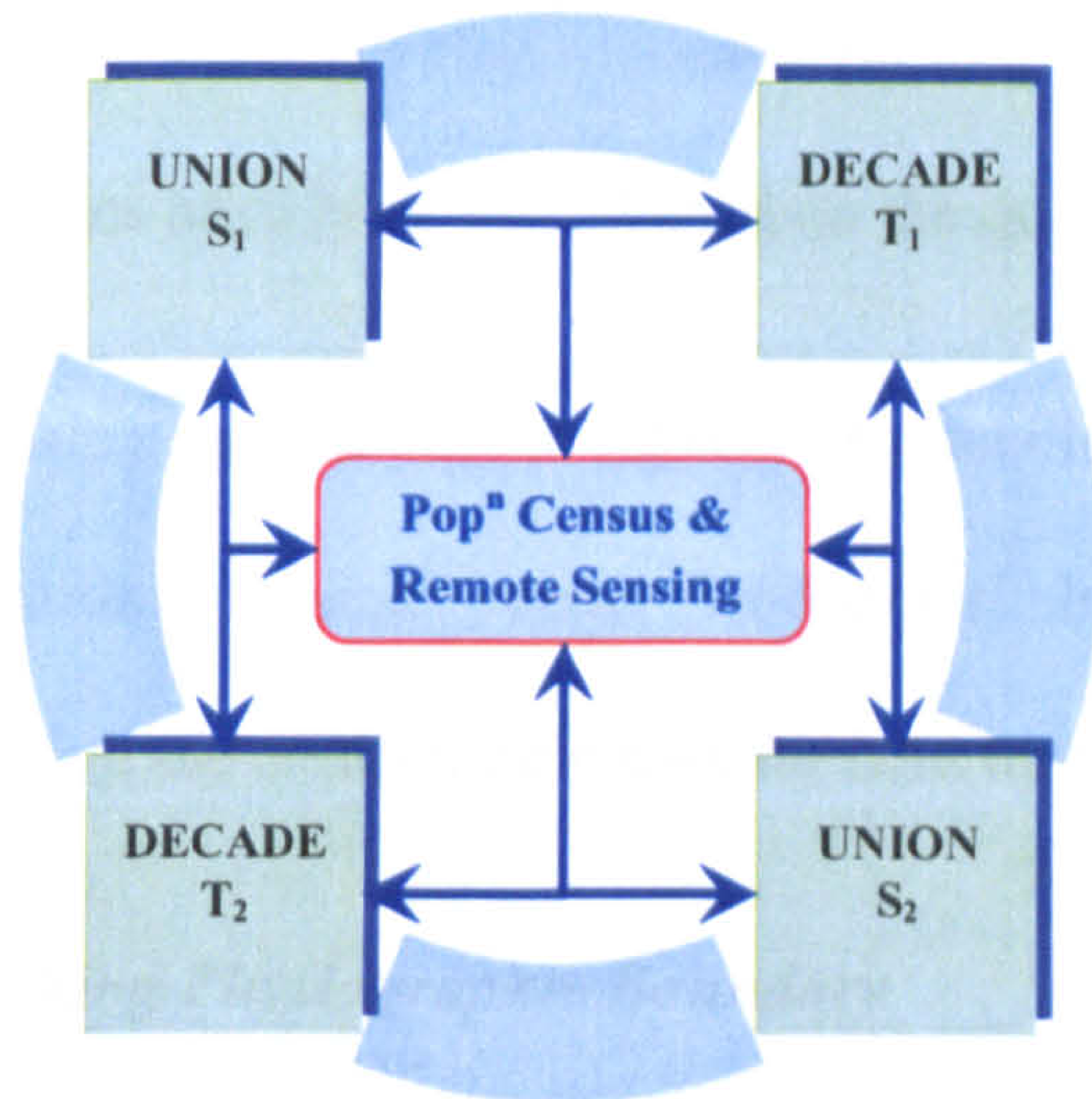


Figure 4-13: Schematic spatio-censual bonds of the transformation system between Time (e.g. T_1 = 1950s, T_2 = 1960s and so on) and Space (e.g. S_1 = Dhamsona Union, S_2 = Savar Paurashava and so on) within the upazila and the respective complex role of decennial Population Census data and Remote Sensing images with ST.

As I have already mentioned, the population increase in Savar upazila has not been even. There are some local factors which attract population or repel at Union level. We can discuss this on the basis of each Union of Savar upazila. The following discussion will be in two parts for each Union. The first part has been analysed based on satellite images and aerial photos to give the context of the area, based on feature interpretation techniques. The second part is mainly based on the census reports of 1951, 1961, 1974, 1981, 1991 and 2001, with the help of the contextual analysis of images. The population figures help to understand and justify the local complexities on their own merits. In both cases, field data were also integrated where necessary. In the municipal area as an example, we can see the massive developments in one area from the images and rapid population growth also as an impact, but we do not see the name and nature of the infrastructures from the air, space or censuses. If we know the meaning of signature on land for the municipal through field visits, then we can match the evidence more professionally. One of the main aims of the following section is to develop a contextual and censual base with the next chapter where transformations have been tried, based on the qualitative database.

Now, from the remote sensing and the census aspects, the detailed approach is much more complex, particularly regarding 'Union' versus 'land types'. In the following section, I will discuss the reason behind the conflicting issues for land transformation study.

(a) Land Types for Delimiting Physiographic Boundary

To study the land transformation regarding settlements expansion, it is to be decided which land features are most relevant to the expansion of occupied land, but the common criterion is to be flood free land from any prolonged inundation, so the features area:

(1) *Chala* land, which is the most important for the future urban expansion. The land is flood free and relatively large in extent. The chala land is highly associated with the floodable *byde* land;

(2) *Tek* Land, which is like an island but tectonically was part of the chala land. The tek is isolated by the surrounding deep basin or depression known as deeply floodable *chwaks*.

(3) *Kandi* land, which has emerged from the river shifting and in abandoned channels; this is a natural levée of the nearby river. This land has always been at risk of flooding but may not necessarily have floodings problems every year. It is the relatively flood-free higher ridge of the *char* lands.

The other land types at this stage are not part of the built-up area expansion. But they may be involved in the settlement expansion when the entire upazila's high land will be saturated by the built-up areas. They may come from first byde, then char and finally chwak. In case of Savar, it is assumed that it may take half a century to occupy the lowland. In that case, Savar protection embankment (like Dhaka Protection Embankment) may be required to accommodate additional people.

(b) Union for Delimiting Administrative Boundary

This is important to know that the boundary of the Union is very important for the following reasons:

- All of the census database is based on administrative boundaries rather than feature-specific, so the data set available here is based on the Union Boundary, a subunit of the upazila. To integrate census and RS data, we need to compromise with this boundary;
- The Union elects a Union council locally known as the Union Parishad, and all of the local development activities involve this council;
- The master plan of RAJUK for the upazila was prepared based on the Union jurisdictions. These are known as the SPZ (Strategic Planning Zone). All of Unions (except Simulia Union) of Savar belong to the SPZ-17a, SPZ-17b and SPZ-17c;
- The upgrade of a Union to Paurashava, is mainly based on the Union boundary; and
- In most cases, the development grants and disaster management programme consider the Union as a base unit.

We know by now that there are 13 administration subdivisions but it is not wise to discuss all of them at the same time. So I have decided to follow a compromise approach so that we can get some Unions which represent the overall picture of similar administrative units holding broadly same the physiography in Savar upazila. This is termed a unionographic approach.

4.3.3. Unionographic Analysis: A Compromise Approach

From the remote sensing context the land feature specific study is important as the land features are possible to delimit while from the population census point of view, the administrative boundaries of a Union-specific analysis are satisfactory a data collection framework. But to merge both in an integrated process, we need to find out compromise solution, where both Union and features are matched together. So Table 4-8 gives a practical approach for further investigation in an integrated form. The transformation is highly relevant to the land types like chala, tek and kandi. At an early stage (e.g. until the 1950s) these lands were modified only by proximity to the river systems. But in developing phase the focus shifted towards the highways. Finally, the recent development tendency has been mainly pro-government initiatives like the establishment of EPZ and its aftermath effect on the population growth.

Table 4-8: Basis of the generalised investigation approach to the land transformation study

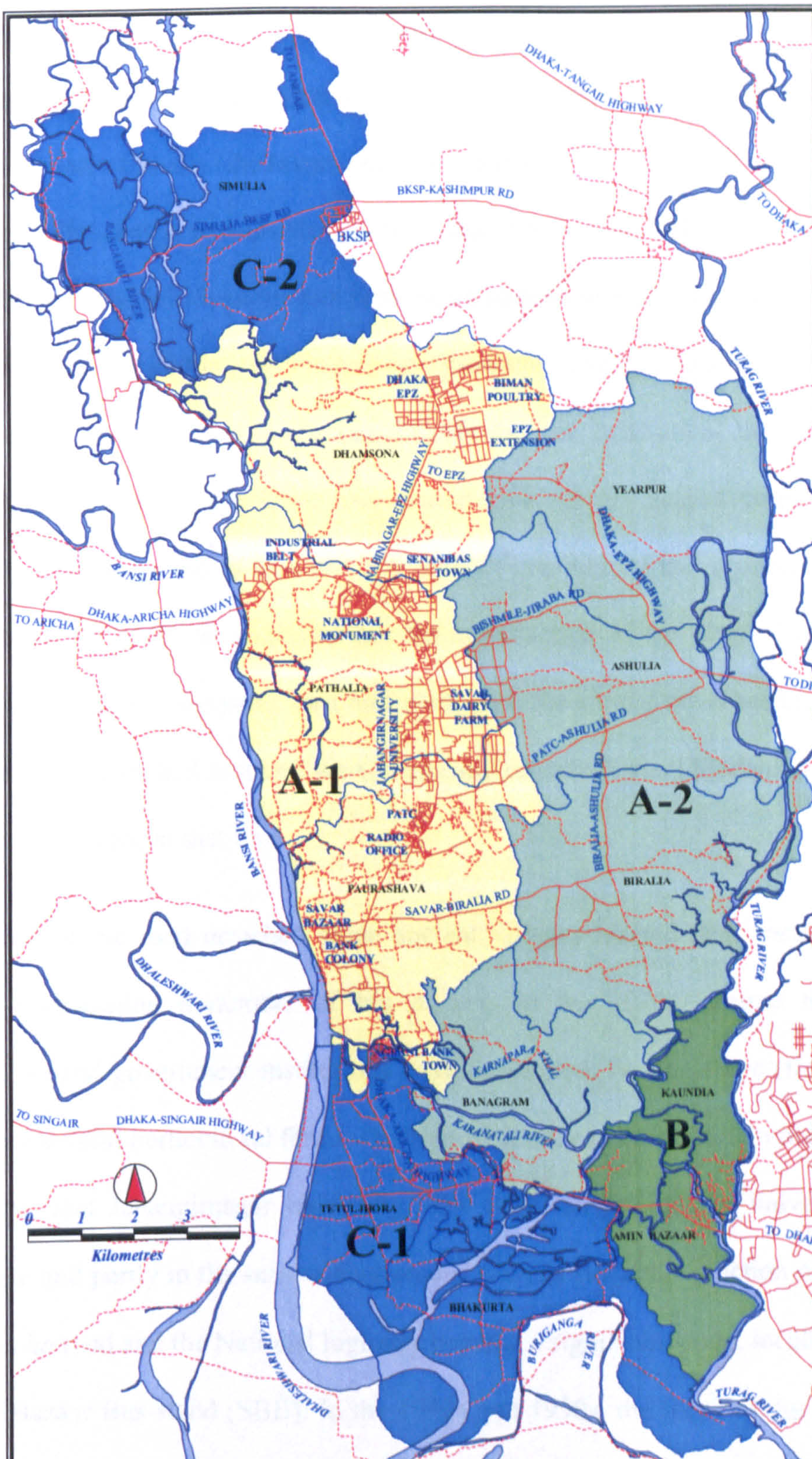
<table>
<tr><th rowspan="2">Unionography: Unions are classed on land types</th><th rowspan="2">Associated floodable land Features</th><th colspan="2">Mode of Transportations</th><th rowspan="2">Settlement Expansion Potentials</th><th rowspan="2">Grouped Unions</th></tr>
<tr><th>Influence of Riverain (pre-development) Networks</th><th>Influence of Highways (pro-development) Networks</th></tr>
<tr><td rowspan="2">Chala Unions (Forest vs. Orchards vs. Urbanisation)</td><td rowspan="2">Dissected by narrow strips of Bydes</td><td>Bansi River: Entranced narrow Channel</td><td>Dhaka-Aricha (Since late 1960s)</td><td rowspan="2">Expandable to gaon, unsuitable bydes</td><td>Paurashava, Savar, Pathalia, Dhamsona.</td></tr>
<tr><td>Turag River: Entrenched Channel with wide basin</td><td>Dhaka-EPZ (Since Late 1990s)</td><td>Ashulia, Yearpur, Biralia, Banagram.</td></tr>
<tr><td>Tek Unions (Agri. vs. Brickfields)</td><td>Engulfed by very low & vast Chwaks</td><td>Confluence of Turag and Bansi</td><td>Dhaka-Aricha (Since early 1960s)</td><td>Saturated dias, unsuitable chwaks</td><td>Amin Bazaar, Kaundia.</td></tr>
<tr><td>Kanda Unions (Agri vs. River Shifting)</td><td>Huge low Sandy Floodplain Chars</td><td>Dhaleshwari-Buriganga: Meandering Channels</td><td>No direct influence but have indirect influence of nearby Highways</td><td>None: no kandi left, unsuitable chars</td><td>Bhakurta, Tetuljhora, Simulia.</td></tr>
</table>

Source: Author, 2003

As observed from the above parameters, the land transformations were both feature and Union-specific. Thus the table classifies the Unions by both their own administrative name, and their specific geographic features. I have termed the feature theme as *unionographic* instead of physiographic, so that *unionography* can hold the data of census and remote sensing simultaneously on the basis of similar characteristics. I classified all unions based on feature specifics, and reduced the number of unions from 13 into three classes integrated with the 3 physiographic units (Figure 4-14). Chala Unions have two further classes based on the influence of the rivers like the Bansi (Figure A-1 of 4-14) and Turag (Figure A-2 of 4-14). For example, I used *Chala* unions rather than Savar, Pathalia and so on, which implies both very general and simplistic characteristics and administrative jurisdiction. So the classification is based on the following categories:

(a) Chala Unions: Example of the Paurashava

Savar Paurashava (including Savar Union) is a notable union of a Chala Unionographic division (Figures 4-15 and 4-16). Several types of transformation have happened over time on the banks of the Bansi and Turag rivers termed here as chala unions. In general, the visible trend of transformation happened from south to north along the path of the national highways. Most of the modern infrastructures, industrial expansions and development works are concentrated in this region at the cost of the former rich forest resources, historical heritage and long-term traditions. In the chala unions, gaon refers to a village and byde stands for agricultural field as lowland.



Source: Author, 2003

Figure 4-14: A broad unionographic division of Savar upazila overlapping with rivers and roads. Index: A= Chala Unions (Bansi River based = A-1 and Turag based A-2), B = Tek Unions and C = Kanda Unions (C-1 = Dhaleshwari-Buriganga Floodplain and C-2 = Rangamati Floodplain).

Savar is located on the east bank of the Bansi River. In the central west part there are several byde lands around its border. In the 1953 aerial photo, the northwest part of the Union, particularly Chhalia (the biggest mauza in Savar Union at about 5 km^2), was under dense forest. The central part is relative low chala, which goes under water for weeks in the rainy season. The mid-western part is the main settlement area. The southern boundary of the Union is embraced by the khals/rivers (Karanatali and Karanpara). So, if we draw the picture of the 1950s, the south was suitable for rice cultivation, the east for rural settlement, the north-east for forest, the central area for dry season crops, and, most significantly, the mid-western area was the heart of commercial and economic activty at that time. But the 1962 image shows that the construction of the national highway has divided the Union into two parts, east and west. And the central government, in order to establish a dairy farm, had acquired the Chhalia and relatively small Madanpur and Kalma (western part) mauzas at that time.

Construction of the road detached some ancient villages located near eastern Dakshin Dariapur, endangering a number of big *pukurs*. In the 1970s, around the national highways, several government institutions were developed. Among these (from south to north), were several horticultural farms, the high frequency radio station, military and civil dairy farms, and Jahangirnagar university. The dairy farms and the university partly located here and partly in the surrounding unions. At this stage, the junction of the Savar-Biralia *katcha* road and the National highway became a significant node, locally known as the Savar Bazaar Bus-stand (SBB). In the 1980s and 1990s, the focus of the commercial and residential areas shifted from the west to around the SBB zone, and the government declared it as Savar Paurashava in 1991 to provide urban benefits. By 2001, virtually the entire Savar Union had become a densely populated settlement area except for the southern low-lying areas and the land acquired by the government. The *pucca* road network has also dramatically increased over the last decade.

'Savar Union' versus 'Savar Paurashava' in 'Savar Upazila'

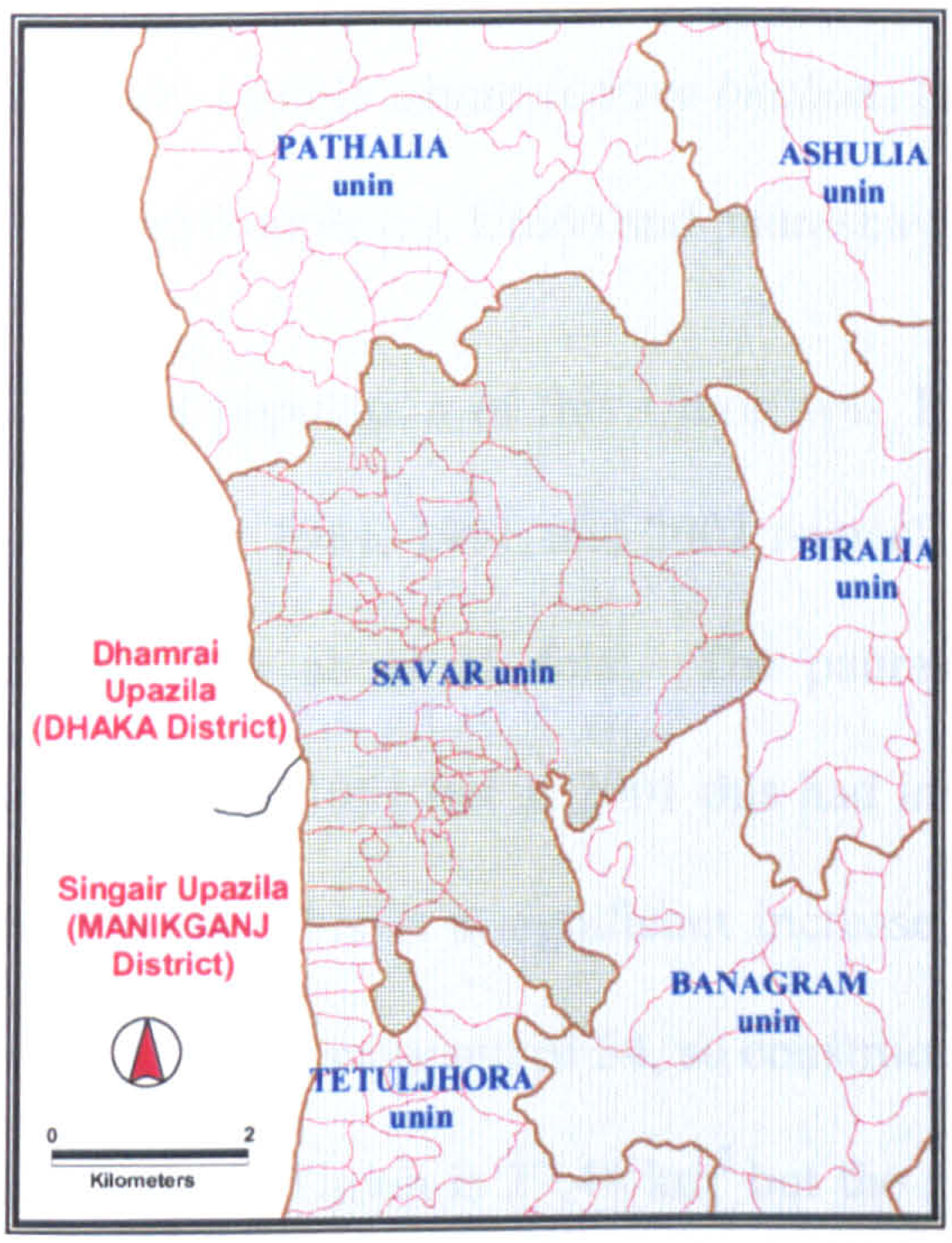


Figure 4-15: Savar Union (27.48 km^2) was the most significant Union over its long history until 1991, which contained all the major headquarters (HQ) of the Savar upazila. Since 1992, the 'scattered and peculiar' shape of the current Savar Union is highly regrettable as seen in the right hand figure. Unusually the head office of Savar Union is in Savar paurashava as it is unsuitable to shift elsewhere even in the current Savar Union.

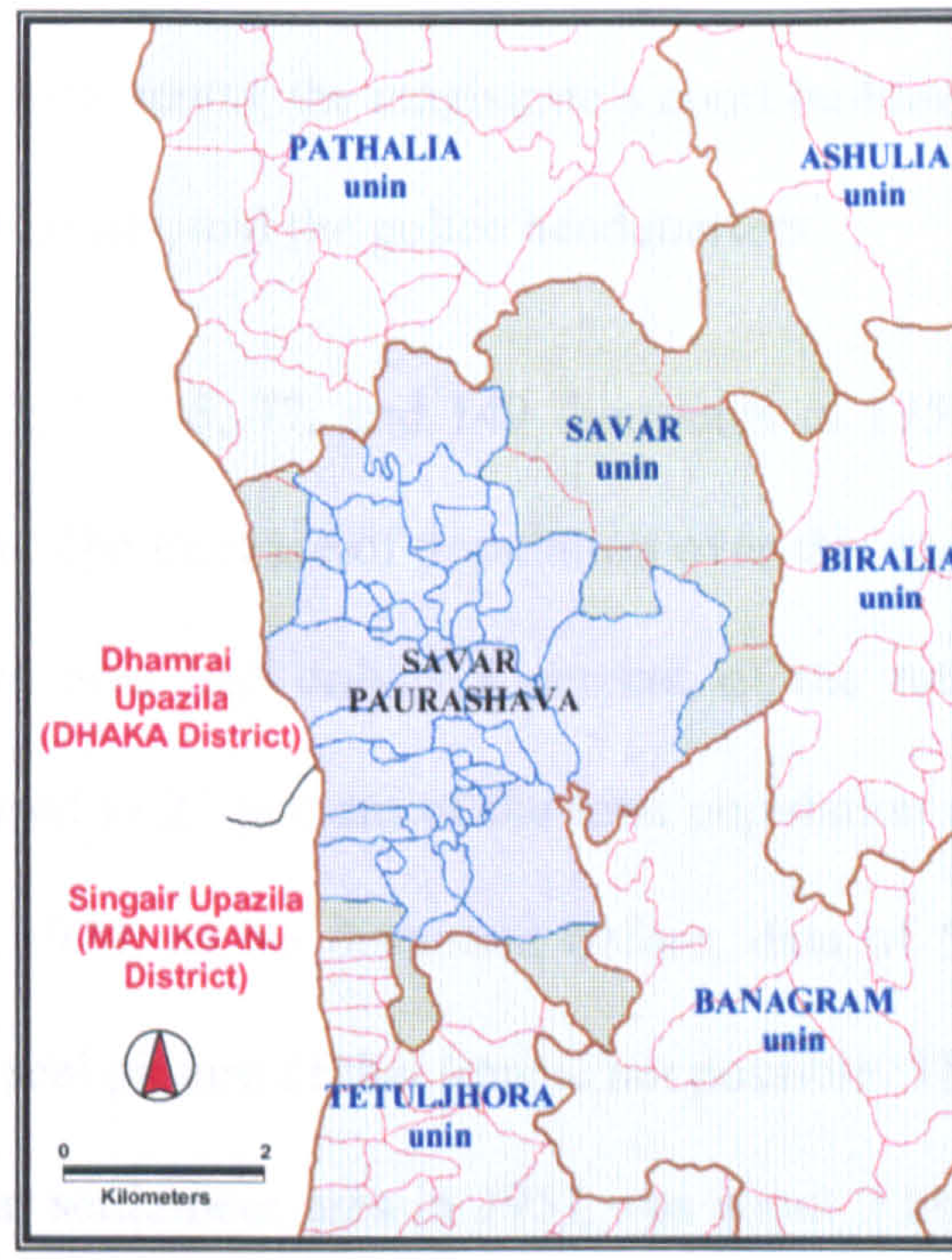


Figure 4-16: In November 1991, most (15.91 km^2) of Savar Union was upgraded as Savar *Paurashava* (local municipal) and the marginal dissected mauzas remained in Savar Union. Savar upazila and Savar Union Headquarters also remained there. In the text, Savar Union including Paurashava means the Former Savar Union (until 1991) of Savar upazila as boundary shown in the left hand Figure.

In the prehistoric period, what is now the paurashava was the centre of earliest population and administrative centre for the surrounding region, including adjacent Dhamrai and Kaliakoir upazilas. As an example, a 'Mud Ford' is still located in the Bank of Bansi River very close to the Savar Bazaar, which was built in the 7th century. Since 1951, all of the upazila level head quarters have been located here. Savar Bazaar is famous for its two days of haats in this region, on Saturday and Tuesday. These are important for retail and wholesale businesses, mainly related to agro-based products. Currently, the wholesale market is more important than the retail trade. After the establishment of the Paurashava in this Union in the early 1990s, the Bazaar Bus-stand is now more focused on retail business. All important secondary and higher educational institutes are here, along with hospitals, upazila administrative *bhabans* (establishments), the magistrate's court building, shopping complexes, Union and paurashava parishads, and the police headquarters.

The total population of this Union was 10, 12, 13, 36, 77, and 149 thousands in 1951, 1961, 1974, 1981, 1991, and 2001 respectively. The increase of population over this span of time was about 15 fold. The paurashava area had only 7.5 percent of the total population in 1951 but in 2001 this had increased to 21 percent of the total population of the upazila. This is a significant increase. In 1974, as we discussed before, data of 50 mauzas was missing out of 54, so constructing real picture of that time is not possible. The size of Savar Union is 27.48 km^2 but the actual settlement area in 1951 was about 7 km^2 and in 2001 16 km^2. But if we consider only the paurashava part of the Union, about 90 percent of the area is populated and only 10 percent of the area is now left for further development. This remaining area is crucial for the overall drainage system of the paurashava, being parts of bydes, rivers, and khals, in other words the low-lying flood-prone land. Due to unplanned settlement and infrastructural growth, Savar Union is the most polluted Union in the region. In the west, the Bansi river is gradually narrowing every year, and, as a result, the landmass of this Union is increasing. The acquisition of this landmass by force has caused big disputes among rival interest groups.

Remote Sensing can help us to explain the reason for the massive and constant population growth in the paurashava (Table 4-9):

(1) In the 1950s, the area was a river port and the commercial and economic-administrative centre of the upazila.

(2) In the 1960s, the construction of Dhaka-Aricha Highway changed the focus from a river to a road-based economy. The presence of the road invited massive land acquisition in this region on cheaply available chala lands.

(3) In the 1970s, Savar was connected by road directly with the capital and the north and west regions of Bangladesh after the construction of several significant bridges on the Dhaka-Aricha Highway.

(4) In the 1980s 'Savar Thana' was upgraded as 'Savar upazila', hence, all of the upazila headquarters and institutions were built here. Moreover, population growth of the adjacent capital city of Bangladesh gradually became overpopulated and the price of land was out of the reach of the common people and there were no highlands left for development. So Savar Union got extra attention to attract population due to easy communications, cheap land and a peaceful environment with chala land.

(5) In the 1990s, most of the Union was declared as a Paurashava (local municipality). Moreover, RAJUK also declared the area to be under their jurisdiction in 1996 and expanded the territory of Dhaka Metropolitan City. This declaration and the establishment of the EPZ in Dhamsona Union caused the population influx to accelerate.

The land of Savar Union (including the paurashava) is not completely under the local authority, because, the University, the Dairy Farm, the PATC and other government institutions run their own development and administrative bodies. They never discuss or share their plans with the surrounding elected or executive authorities. The entire northeast part of the Union is facing these challenges. The density of population is relatively very low on the government-controlled landmass.

The entire Chala Unionography will have the similar impact like Savar Union (including paurashava) on the bank of Bansi or Turag basin once they are connected properly with the capital Dhaka.

Table 4-9: Summary of major events of land features transformations of Savar Union/Paurashava

Major Land use / land cover relevant to Savar	Particular Location in Savar Union and Paurashava	1953 AP	1962 CORONA	1972 CORONA	1984 AP	1990 AP	2000 IRS
Shaal deforestations	North-eastern *Chalas*	X	X	X			
Orchards disappear	South-eastern Chalas	X	X	X	X		
Land Acquisition	Eastern *Chalas*		X	X			
University Expansion	Northern part (west of the Highway)				X	X	X
Pukurs Disappear	Central and north eastern Chalas				X	X	X
Building upazila Headquarters	Central-west				X		
PATC constructions	Central northwest				X	X	
Paurashava Structures	Southeast					X	X
Dairy Farm	North-eastern Part (east of the Highway)		X	X	X		
Bank Town	North-east (Mainly east Highway)					X	X
Bank Colony (proposed and later abandoned)	Central west				X	X	
Scattered Private Industrialisation	Around southern Dhaka-Aricha Highways				X	X	
Prominent Schools and Colleges	Central west	X	X				
Pucca Roads Concentration	All over the western Highways wards				X	X	X
Construction and upgrading of National Highways	Middle of the Union (south-northward)		X	X	X	X	X
Village Destruction	North-eastern		X	X	X	X	
Byde Pollution	South-eastern				X	X	X
Influence of Savar Markets	Near Bazaar Stand					X	X
Agricultural Activities	Central Part: *lower chalas*	X	X	X	X		
	South-eastern: *bydes*	X	X	X	X	X	X
Influence of Ancient Growth Centre	Savar *haat*: Mid-west part close to the river	X	X	X	X		
Influence Recent Growth Centre	Near Savar Bus stand: central Union around the national highway				X	X	X
Major Rural Settlements Concentrations and Population growth	North-western				X	X	X
	Eastern Villages						X
	South-western mauzas			X	X	X	X
Major *Paura* Settlements Concentrations and Population growth	On the entire mid-western part				X	X	X
Massive Commercial Housing Project	Central north-east				X	X	X

Source: Interpretation of RS Images and Overlapped Census Data, 2002

(b) Tek Unions: Example from Amin Bazaar Union

In the zone of Tek Unionography, dia refers to built up areas while chwak indicates the low land mainly suitable for agriculture. The Amin Bazaar is a part of Tek Unionography. The Union is encircled by Kaundia Union in the west, Banagram in the northwest, Tetuljhora in the west, and Bhakurta in the southwest of Savar upazila. Dhaka City Corporation is located in the east. The centre of Dhaka is a close distance from here by road.

The size of the Union is about 7.78 km^2 but the inhabitable land is only a half of a km^2. The land is located on both sides of the road at the entrance of the Dhaka-Aricha Highways from the Capital through to the Gabtali (bridge) area. Also here is the southern part of the small river Karanatali, which emerges from the Bansi and falls into the Turag river. Historically the Union was dependent on the river economy but from the late 1960s it was connected with the metallic bridge and highways. As it was the closest part of the Dhaka city by road, the concentration of population here was due to Dhaka city overspill. That is why this is the most concentrated part of Savar historically.

Chwak, the low land, surrounds this territory. Primarily it was very suitable for the agricultural activities, but due to its extraordinary location, its underlying clayey soil quality, good communications and the demand of nearby rapid urbanisation, the area changed its focus from agrarian use to brickfields. Now this is the biggest brickfield (*iter-bhata*) belt in Bangladesh. As seen on the images, in the lowland there is a *khal* in the middle of the Union flowing from the Karanatali to Turag rivers, which is now almost on its last legs due to the construction of roads and massive brickfields. Settlement clusters in the Union are like islands, particularly in the wet seasons. The southwest part of the Union is under the *char* category of land features. From the image interpretation, it is clear that settlement expansion in Amin Bazaar is not possible, but its compactness or saturation may continue for decades ahead. After filling some lands, parts of the low-lying areas adjacent to the highway have been reclaimed for the settlement expansion or small commercial activities like shopping centres. The biggest mauza in the Union as well as in Savar upazila, 90 percent of the Union (9 km^2), is Bara Bardeshi (locally known as Chandpur). This was under agricultural activities until 1980s but now majors on the brickfield economy. Almost all of the brickfields are located in this particular mauza. Two other small mauzas, Binodbari and Dhoborai, are in the same situation as Bara Bardeshi.

Based on the above context, this is one of a few unions that has no additional flood-free land to expand into around its current settlements. Since 1951, the increase of settlements on its periphery was only from 0.34 km^2 to 0.46 km^2. The total decennial population figures for this Union between 1951 and 2001 were 6,287; 7,059; 9,329; 13,499; 26,129; 33,140. It is difficult imagine of the density of population on this tiny area of land. The Union shares an almost steady proportion of the upazila ranging from 5 to 7 percent. If we calculate the actual density on the high lands here, it is more than 70,000 people per km^2. This is an extremely densely populated, backward area of the upazila. We can assume that the density will gradually increase over time, which will create a tremendous pressure on the land ultimately if we do not consider any plan for that area on an urgent basis. Though the land is not under municipal control and there are no urban facilities, the settlements have grown without planning permission. The major economic activities here are transport and brickfields. Other minor activities are relevant to agriculture and retail trades. The most populated mauzas are Sujanagar, Makinnagar, Mamud Mirdhartek, Begunbari, Hijli, Chhoto Baradeshi, Baradeshi and Salipur. In brief, the transformation of the land has been as follows (Table 4-10):

(1) Amin Bazaar has a very limited amount of high land (*dia*) and is the closest Union from the capital city by road;

(2) Since the 1950s, the settlement density is the highest amongst all of the unions of Savar;

(3) In the 1960s, road construction gave this Union entrance status in the upazila;

(4) In the 1970s, it was firstly affected by the Dhaka's population overspill;

(5) Since the 1980s, in the lowland (*chwak*) for the first time in history, mauzas were converted into a unique Brickfield zone.

Only Amin Bazaar and Kaundia Unions are under the Tek Unionography. Kaundia will face also similar sorts of experience to Amin Bazaar.

Table 4-10: Summary of major events of land features transformations of Amin Bazaar Union

Major Land use / land cover relevant to Amin Bazaar	**Particular Location in Amin Bazaar**	1953 AP	1962 CORONA	1972 CORONA	1984 AP	1990 AP	2000 IRS
National Highways	Northern part (east-west)						X
Agricultural Activities	All Chwaks of the Union	X	X	X			
Brickfield Expansion and Pollution	All Chwaks of the Union				X	X	X
Construction of Amin bazaar Bridge	North-eastern mauzas			X	X		
Rapid Population growth	Only on limited tiny *Dias*				X	X	X
Affected *Khal* Network	Only Baradeshi Khals on the southwest mauza					X	X
Potential Trend of settlement Expansion		No way as there is no high land left in the Union					

Source: Interpretation of Images and Overlapped Census Data, 2002

(c) Kanda Unions: Example of Bhakurta Union

In this zone, in general only kandi is suitable for settlement construction and chars are lowland and vulnerable to flood for about half a year. Bhakurta, Tetuljhora and Simulia can be broadly classified under this category. As an example, I will discuss Bhakurta Union. Bhakurta is the southern most Union of Savar upazila and is part of the most active floodplain in the study area. Tetuljhora is to the north and Amin Bazaar to the norheast. In the east, the backward and marshy part of the Dhaka city corporation is found. In the south, Keraniganj upazila is located alongside comparatively narrow, abandoned channel of the Buriganga River.

Due to the rapid change of the river channels, the western part of the Union was highly affected between 1950s and 1970s. After that the area become relatively stable and danger free due to the river bank erosion. Three villages named Musurikhola, Chunar Char and Chaira mauzas were the most endangered mauzas due to the shifting of the course of the Dhalaeshwari river. A significant number of settlements were destroyed here. Local people struggled to cope with the constant shifting nature of the riverine landmass at that time. This Union is the land of *kanda* where linear shaped villages are visible on the natural levées of the meandering river. There is no place to expand and the population is highly squeezed together. There are no *chalas* or *bydes* located in the area. Two big rivers of the region the Turag and the Dhaleshwari (more than 500 metres wide), flow both sides of the Union, and are connected to the Buriganga river (at this point less than 50 metres wide). This Union contains the most fertile agricultural land of the upazila. There is no pucca road available in the Union. In the wet season, local boats are the only transport medium for both peoples and commodities. The surrounding char lands go under floodwater for nearly six months with a very strong current due to the complex and unstable river network. The pattern of settlements is arc shaped. The width of the settlement strip is only a few meters and its length is less than a kilometre. Homestead forests are located in the north (or north-west) of the each settlement cluster. In the dry season, the villages are linked with the katcha road around the aayeels. The area is highly dependent on agricultural activities.

On its 20 km^2 of land, Bhakurta has accommodated at each census 14,810; 16,776; 19,843; 26,260; 33,113; and 38,025 people on only 2.52 km^2 of *kanda* land suitable for settlements (about 4 percent of the total inhabited areas) with no expansion possibilities. The most important characteristic of these villages is that they are almost homogeneous and are the most populous part of the region. In 1951, it was home to 15 percent of the population but now it only shares 6 percent. Due to a limited inhabitable landmass, the population growth rate could not be maintained as in other parts of the upazila. These areas have no probability of further urbanization in future (Table 4-11).

4.3.4. Complementary Roles of RS for Population Census

From the above discussion and examples, it is very easy to establish the complementary roles of remote sensing and census data using GIS approaches. By the integration of information from image interpretation and census data help to assess the following aspect of land transformation: the context of population growth; enhancing census data resolution, finding out missing mauza data and factors responsible for land transformation at the upazila level.

Table 4-11: Summary of major events of land features transformations of Bhakurta Union

Major Land use / land cover relevant to Bhakurta	Particular Location in Bhakurta Union	1953 AP	1962 CORONA	1972 CORONA	1984 AP	1990 AP	2000 IRS
Shifting and abandoning River Courses	Western Part	X	X	X			
Creation of Deeghoirs	Western Part		X	X			
Narrow Roads	East-westward two parallel road						X
Main mode of transportations	Boats (mainly in wet seasons)						X
Agricultural Activities	Eastern Part: *bydes and Chwaks*		X	X	X	X	X
	Most of the *chalas* with irrigations					X	X
Reduction of cultivable land	Western parts	X	X	X	X		
Orientation of Land Transformations	Stable and steady Eastern part	X	X	X	X	X	X
	Very Unstable Western part						
Major Settlement Concentrations	Western territories	X	X	X	X	X	X
Population growth	Entire *kanda* lands at the same time	X	X	X	X	X	X
Potential Trend of settlement Expansion	Unpopulated areas are mainly deeply flooded	No way as there is no high land left in the Union					

Source: Interpretation of Images and Overlapped Census Data, 2002

(a) Context of Population Growth

From the above discussion, there are several factors driving land transformation over time. The major factor was population change. In both maps (Figures 4-17 and 4-18) are the infrastructural development and construction of roads is on the high and flood-free chala lands. In the left hand map, the concentration of major development activities mainly belongs to the highlands, which are very close to the national highways.

In the early 1950s, the low land, illustrated in the Figure 4-18, was the major attraction for the population growth, but currently it plays a negative role in the process of urbanisation. The locations of settlements are also shown in order to understand the link between the map features. All of these features are extracted from remotely sensed images. In the census reports, the background land features, which are crucial for any land transformation in Bangladesh and the influence of structures along the highways, have the most significance in explaining any settlement pattern and expansion. On the one hand, currently the features located in the north-west have a positive impact of the overall population growth in that region but on the other hand the southeast features are less important.

Explaining Index of Figure 4-17:

AEC - Atomic Energy Commission (1978): This was one of the few early large installations in Savar upazila. Here about 300 government officials are stationed.

AFK - Ashulia Floating Corner (2002): A very new zone of tourist attractions in the region and lots of private investors have started several projects very close to this zone, such as Ashulia Fantasy Kingdom, floating tourist spots and several housing projects.

AGS - Agrani Housing Society (1988): It is the most successful and planned privately funded housing projects in Savar and playing a role to expand Savar systematically. A significant amount of houses are already built here.

*AHS - Arunapalli Housing Society (Proposed): The project is progressing with the help of Jahangirnagar University teaching community. The detailed housing plan has already been adopted and very soon the construction work will begin.

*AMT - Ashulia Model Town (Proposed): Ashulia Model Town is the biggest housing project in Bangladesh but there is a still lack of coordination with the Rajuk Master Plan.

BKSP - Bangladesh Sports Training Centre (1987): It is the only government sports training centre in Bangladesh with a mega-complex and facilities.

BLRI - Bangladesh Livestock Research Institute (1990): The centre has huge infrastructures visible from space.

BP - Biman Poultry Farm (1980): One of the earliest and largest poultry complex funded by Bangladesh National Flag Carrier International Airline.

BTZ - Bhomka Training Zone* (1998): This is a training field for the Bangladesh Military for the cantonments located inside or nearby Dhaka. Exposed soils are the main problem here during dry and training periods.

DSBF - Dry Season Brickfields** (1980s): Hundreds of Brickfields are located in this zone mainly operated in flood free periods. Massive pollution happened due to uncontrolled smoke.

EPA - Extremely Populated Area (1980s): These are the early built-up areas where the process of urbanisation started several decades ago without government planning and investment. Now it is a part of Savar Paurashava.

EPZ - Export Processing Zone: x-Extension (1990): This is the biggest secondary economic zone in the region where about 30-40,000 jobs are involved.

GC - Growth Centres (between 1951 and 2001): These are the natural growth centres of Savar upazila where the concentration of development has started due to certain advantages under the rural environment and some prominent haat/bazaar and local business (mainly agro-based) centres are located here.

GDF - Government Dairy Farm (1961): The earliest and the largest land acquisition by the Government was initiated and implemented with German Funding. This is the biggest cattle breeding and dairy farm in Bangladesh.

JU- Jahangirnagar University (1970s): The focal point of recent urbanisation in this region is centred with this university and its gradual expansion.

NM - National Monument (1972): In respect to the memory of freedom fighters in Bangladesh Liberation war in 1971. A large monument and big park have been developed here for the attraction of tourists.

PATC - Public Administration Training Centre (1985): The most intense government-funded training complex for hundreds of bureaucrats each year.

RS - Radio Station (1965): This is the earliest radio-relay centre in Bangladesh and a staff colony is also attached to this station.

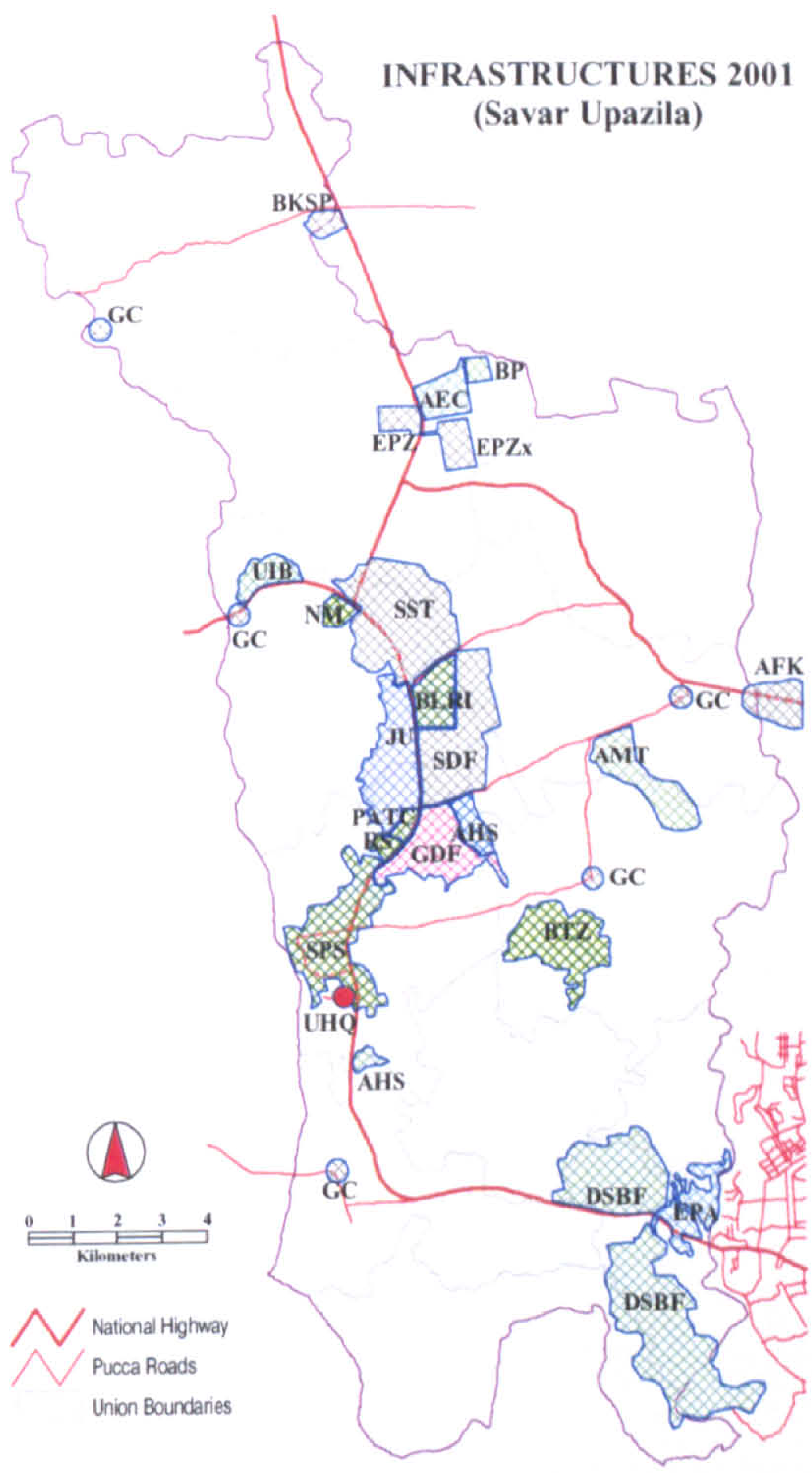
SDF - Savar Dairy Farm (1974): A dairy project controlled by the military.

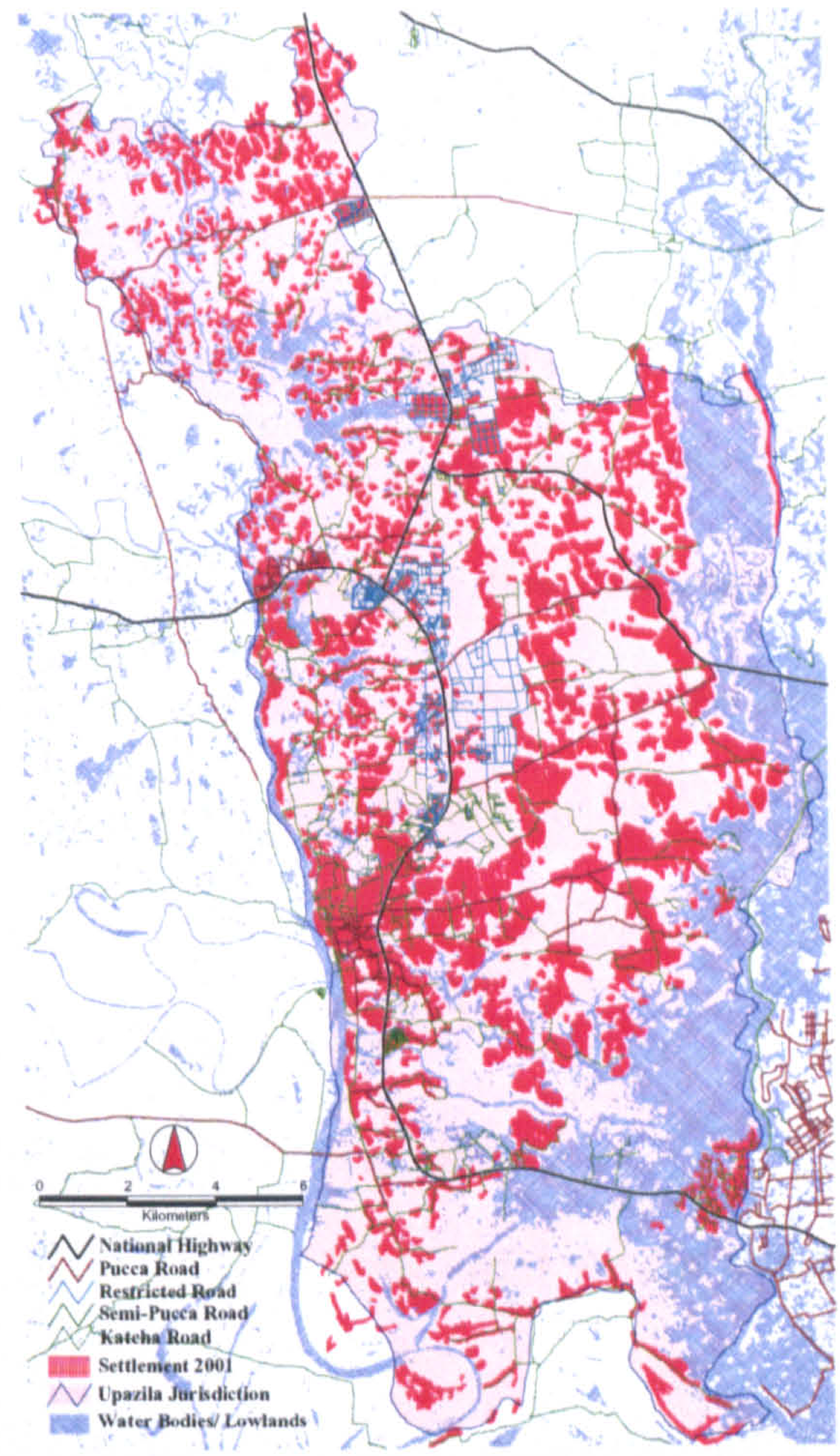
SPS - Savar Paurashava Settlements (1991): Part of the Savar Paurashava.

SST- Savar Senanibas Town (1981): This is a planned military base.

UHQ - Upazila Headquarters (1983): All administrative headquarters of the upazila are located here.

UIB - Unplanned Industrial Belt (Late 1960s): This is the earliest industrial belt of the country, established immediate after of predevelopment phase of Savar upazila.





Index:

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UIB - Unplanned Industrial Belt (Late 1960s)

Note: * The marked features will have impact in the near future as there are no immediate infrastructural activities here;
** It has negative impact of settlement growth due to massive smoke pollution around the region.

Sources: Field Investigations, 2001 and Remote Sensing Images

Figure 4-17: (Left) Based on the high resolution satellite images, most of the important events have been mapped and their years of establishments or expansions over the land mentioned.

Figure 4-18: (right) Location of water bodies and deeply flooded low-lying floodplains and the detailed road network are shown here in correspondence with the settlement locations of the study area.

(b) Enhancing Census Data Resolution

By enhancing the resolution of census data, we can increase the quality of Bangladesh census databases. But is this really possible? Without remote sensing data, probably not, but with the help of high resolution remotely sensed photos, the answer is yes. If we are able to enhance the resolution of population (and agricultural) census data, what are the implications?

In Bangladesh, the lowest unit census surveys has been the mauza since the early 1900s. The boundary of the mauza is constant and the advantage of this sort of data collection is ability it gives to assess long-term change at mauza level. Census data does not yield information to answer the following questions for policy makers, academics, researchers, environmentalists and so on:

(1) Is the entire land of the mauza inhabited or not?

(2) Why do some specific mauzas do not have population data?

(3) If the mauza is partially populated, where are settlements located?

(4) If we can identify the location in the mauza of settlements, what are the reasons responsible for this sort of distribution?

(5) What are the land types and land use in the mauza? Are they constant or changing?

(6) Why is the population increasing or decreasing in a certain mauza?

(7) What is the history of the current distribution?

(8) Is there continuity from the past to present settlement locations?

(9) Above all, what is the reliability of census data? Is there any way to verify it at all?

(10) How can we use census data for spatial planning?

(11) Can we calculate the population data at a sub-mauza scale using remotely sensed data?

(12) Is there any way to assess land transformation using this database?

To solve the above problems, remotely sensed data can play a significant role. It can produce 'metadata' for the census and give a tremendous opportunity to understand the land transformation process and its impact on population change and growth. Census data are ignored in Bangladesh as they cannot provide sufficient information for a planner or researcher but the data taken from space or sky can help to fill a real gap. Without having this base line information, no planning or environmental monitoring programme can be sustainable. So the background and surrounding information can be developed through high-resolution images.

Table 4-12, Figure 4-7 and Figure 4-12 are typical examples from the mauza to sub-mauza enhancement. The table shows that one-fifth of the upazila is out of settled occupation. The inhabited area at sub-mauza level is four times more compact than the mauza-based density approaches in 2001. If we look at the capital Dhaka, almost 95 percent of its area is occupied by buildings and infrastructures. The huge number of clusters (or *para*) is also very significant. A very thin density in Biralia in 2001 is also remarkable.

Table 4-12: A Comparison between mauza and sub-mauza scale data of 2001

Items	Mauza level	Sub-mauza Level
Total Area	284.63 km^2	65.09 km^2
Number of Segments	276 mauzas	2,706 Settlement Clusters (*paara*)
Total Population	635,509	635,509
Density per km^2	2,240	9,763
Populated area of the upazila	100 Percent	22.87 Percent
Base Map	Mauza Map of the upazila used for census survey	Mauza map enhanced with Remote Sensing

Source: Data generated by GIS, 2001

Figures 4-9, 4-12 and 4-20 are the practical application of the enhanced sub-mauza scale census database. The census gave the population statistics, remote sensing has provided the context and visual setting, the GIS provided attributes, boundaries, area and geo-reference data. All approaches together provide the final output for the decision makers. Without these databases, the practical situation in the field cannot be visualised. Any decision makers can understand this sort of map easily and, for them, it is easier to allocate the necessary resources for development.

Figures 4-12 and 4-20 give the areas of concentrations of population. The central focus of population has shifted from places to place, from 1951 to 2001. In 1951 the concentrations of population is around natural water bodes and the highland areas had a very low density and in the context of 2001, when the highland areas attracted more density than the past. Moreover, a lot of new settlements have been constructed here, for example in Dhamsona Union. Due to government institutions in the heart of upazila, natural growth has been restricted and diverted to some extent.

The maps are a reflection of the population distribution (Figures 19 and 20). The following maps are shown here to understand the density of population using an equal area distribution. This classification geo-statistical technique is very important for spatial analysis and planning. Here a classification based on the standard deviation will not work, as the marginal values are extremely low or high. So the equal area classification can be defined as:

> "This method classifies polygon features (e.g. mauzas) by finding breakpoints so that the total area of the polygons in each class is the (approximately) the same. Classes determined with the equal area method are typically very similar to quantile classes when the sizes of all the features are roughly the same. Equal Area will differ from quantile if the features are of vastly different areas (e.g. size of the mauzas are largely varied)" (Modified from ESRI, 1999).

In the upazila data set, the sizes of mauzas are vastly different, so the output is not similar to the quantile classification technique as the population dataset have been normalised by the area.

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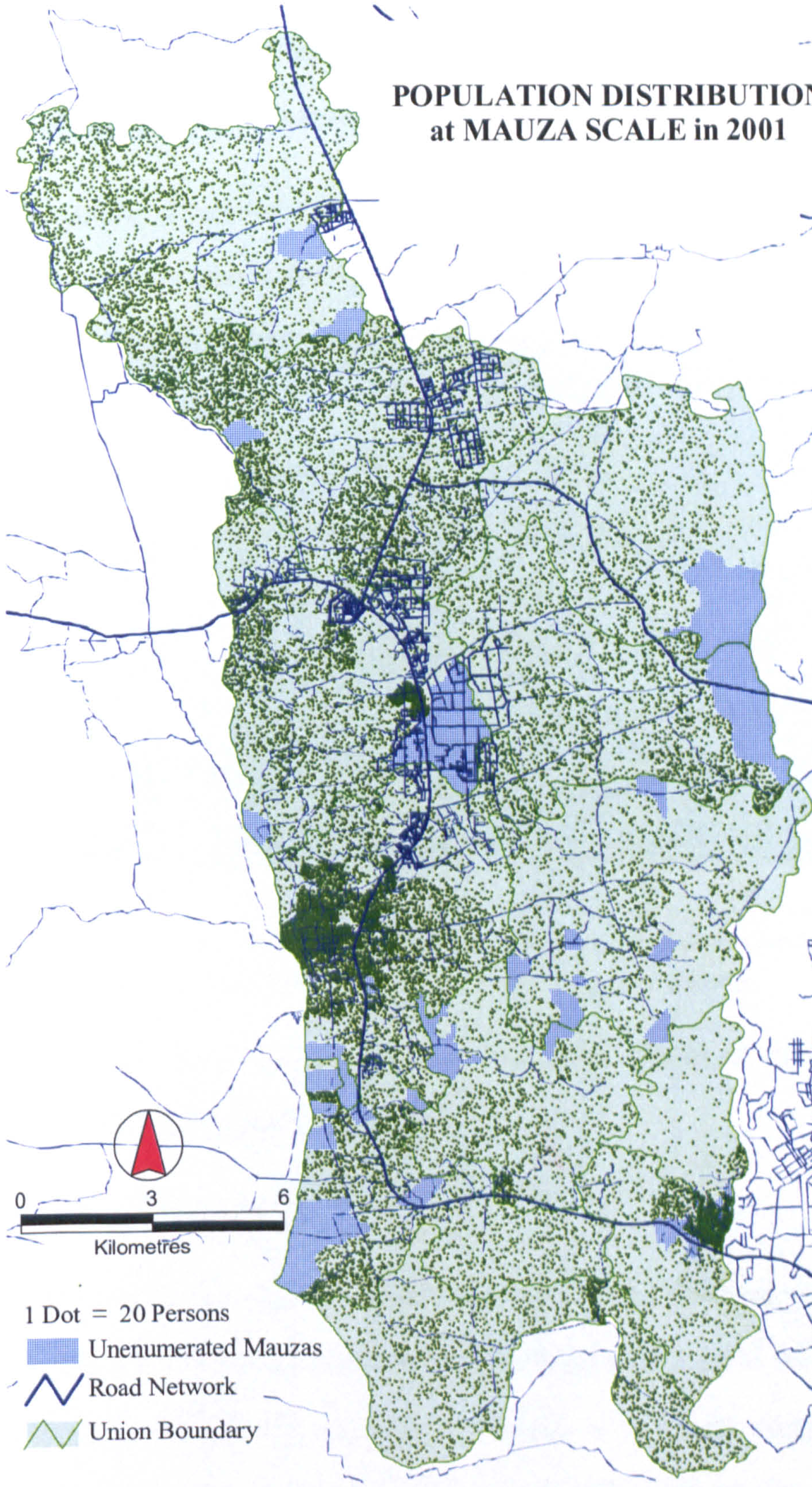


Figure 5-6: Based on Traditional Population Density method, the distribution of population 2001of Savar upazila at mauza level has been mapped.

Population density was high on those highlands with best access to the lowland in 1951 but the density is highest on the highest land currently. Here, quality indicates the total population has been inflated or deflated. There is no doubt that with the help of high remote sensing images it is possible to identify the quality of census databases. Here some examples will help us to understand the nature of population data problems in Bangladesh.

(c) Missing Census Data of Mauzas

In practice, in Savar upazila there should be very few mauzas where population are not living as visible from the satellite (Figure 4-21) and field observation, because of the tremendous pressure of population and demand for land. The Bangladesh Bureau of Statistics (BBS) small area atlas listed all of the mauzas in Savar thana and their physical location and population and the agricultural census reports gives the detail. But the population census reports are silent about a lot of mauzas (not just a few). In the BBS census report some mauzas' data are not available (Table 4-13).

For example, the BBS report does not mention population data and the details of the mauzas, because those mauzas are recognised as being unpopulated. The agricultural census report also did not specify any information on 44 mauzas; they were identified as uncultivated.

It is clear that in the pre-Bangladesh time, the census reports were of higher quality. In 1974, the poor quality of census data is highly regrettable but perhaps understandable in the aftermath of war. At that time about one-third of mauzas were excluded. A significant number of mauzas were not surveyed at all. Most of them were located in Savar Union. The problem with Tetuljhora Union is also remarkable. The census authority failed to incorporate a lot of mauzas. Despite the massive development in this area, there is no evidence that the government is making extra efforts in order to ensure the quality of data.

Most interestingly Bhakurta is the most vulnerable Union due to devastation by a meandering river, but all of the mauza of this Union have been shown here as populated. So the census data has failed to indicate the local devastation. I verified the settlements with the aerial photography of 1951, and only 5 mauzas had no settlements from the missing list and 8 mauzas have been shown as populated.

Table 4-13: According to Census Reports, the list of Depopulated (in fact excluded) Mauzas has been given below.

Union Name	Total mauzas	Excl. 1951	Excl. 1961	Excl. 1974	Excl. 1981	Excl. 1991	Excl. 2001
Amin Bazaar	11	0	0	0	3	2	2
Ashulia	21	1	3	5	3	4	3
Banagram	11	1	3	4	2	3	3
Bhakurta	8	0	0	0	0	0	0
Biralia	30	1	7	7	7	7	7
Dhamsona	15	1	0	2	3	2	1
Kaundia	26	8	4	6	6	7	6
Pathalia	33	5	3	11	3	4	4
Savar (including Paurashava)	54	4	7	50	21	4	4
Simulia	25	1	2	4	2	2	2
Tetuljhora	30	4	7	8	12	11	11
Yearpur	12	0	1	8	1	2	2
Upazila Total	**276**	**26**	**37**	**105**	**63**	**48**	**45**

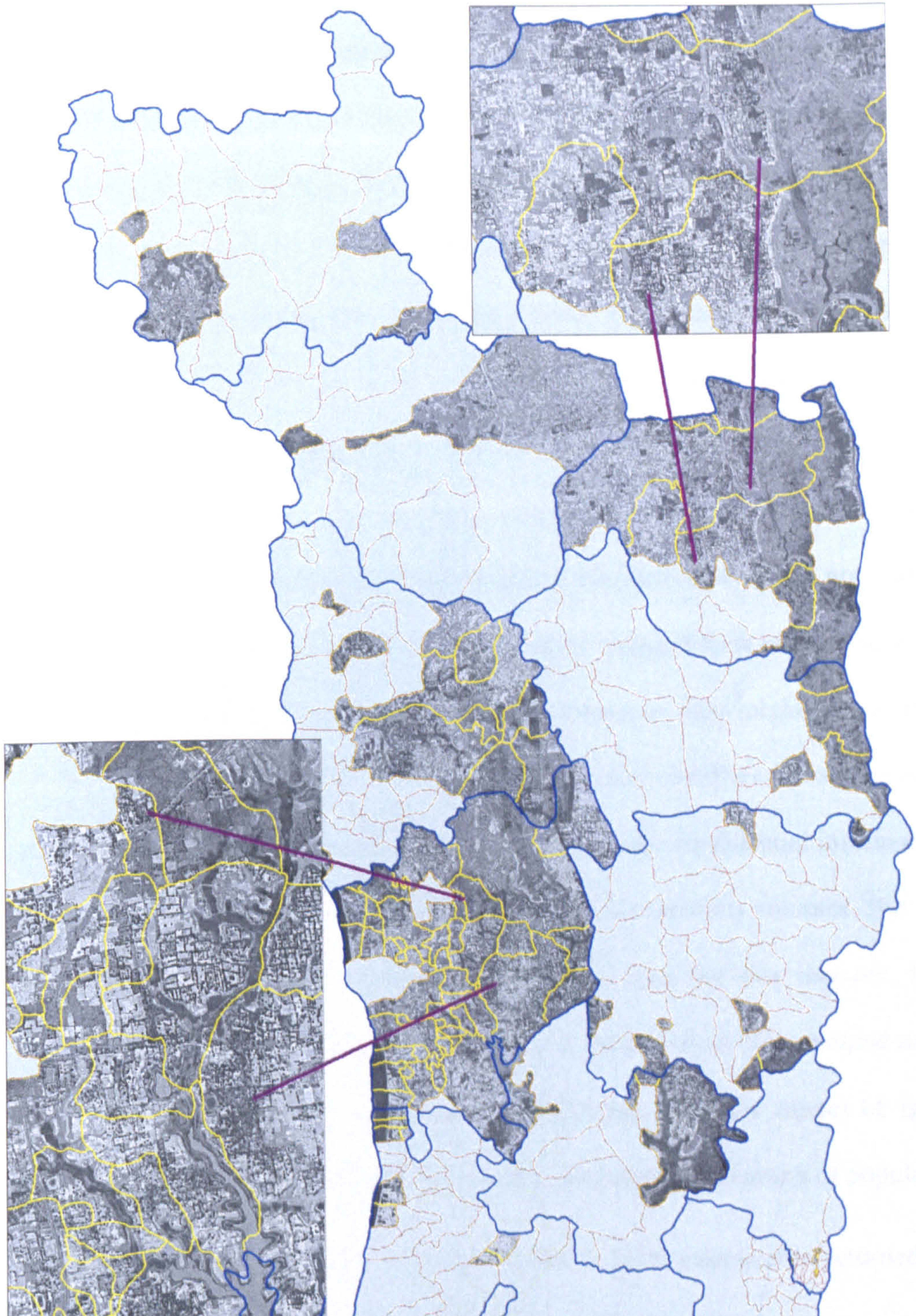


Figure 4-21: Missing population data of 1974 census on the parallel CORONA KH-4b images reflect the clear evidence of unreported settlements. Reported mauzas are covered with masks. Here all 105 missing mauzas of 276 where no population figures have been mapped. In practice, only 21 mauzas were not really populated according to corona interpretation and field investigation. Mainly Savar Paurashava (including Savar Union), Yearpur and Pathalia Unions are affected seriously due to gross negligence of the field enumerators. However, missing mauza data are very common in Bangladesh during the decennial census survey but not at his large scale. High resolution remote sensing can play a remarkable role in order to enhance the quality of census data and to verify unenumerated mauzas. Inset examples of images with higher resolution show particular detailed settlement locations.

I carefully planned my visit in the field to coincide with the carrying out of decennial census survey in Bangladesh to observe it in 2001. It gave me a unique opportunity to understand the problems *in situ* as I became aware of the scale and nature of problems in our primary database. I talked to the field enumerators about why mauzas are not included and the reasons responsible for that. In Bangladesh, most of the enumerators are taken from the local Union particularly those who are jobless. I was very shocked by some of quotations noted during informal interviewing during the census survey. Our team observed so many problems, but here I will cite only a few of them, which can be monitored or at least explained from the photo interpretations. In front of a movie camera or voice recorder enumerators did not want to tell us the facts as they did not want any evidence, but in private they gave us more detail. I have changed their names and will not give the enumeration block number of the relevant mauza as they might face a judicial enquiry if their identity is found out. In Bangladesh like most countries, before the official publication of census data, they are not allowed to provide any confidential information. It takes 3-4 years to publish the detailed census report in zila (district) volumes. But in the long-term interest of the country and my limited time span for this research, it was essential to reveal the reasons for these gross errors at ground level. We assumed most of the collected of census data was correct but the following problems cannot be ignored because they are responsible for about a 5-7 percent error of undercounting of population.

1. For a mauza where there no population at all, a poor enumerator returned it as populated.

    "If I did not show the population on the form, I would not get the payment as an enumerator of this area. To be honest, that is why I showed the false figure, which has no population. The government also made a mistake. Why did they suggest to count this mauza, since they should know that this is a very low lying agricultural land and goes under deep water for more than seven months, you see, there is no sign of inhabitants at all and it is also virtually impossible!" Karim, Local Enumerator, Bhararia mauza, Tetuljhora Union.

2. There are several mauzas which in each census year are not enumerated. So we drew the attention about this issue of a local supervisor. He said:

   "The name of the mauza you mentioned is not in the list of BBS papers, why should I count them? They will not give us any additional reimbursement if I include it as they did not record the mauza name might be by mistake or due to gross negligence. And this is the problem of Dhaka Head Office not ours." Sarkar, Shalipur mauza, Amin Bazaar Union.

The above two problems can be solved easily through high-resolution satellite images. Government can do these jobs easily. But for the following problems it requires some sophisticated image interpretation techniques, which can be made applicable to the Bangladesh rural society.

3. I talked to an enumerator about why he stopped surveying mid-way. His response was:

   "During our training, the field supervisor told me the estimated population would be 1000 per enumerator of an area, but when I started counting the number reached at that level at half way. Why should I count the rest of the population if I do not receive extra payment for that?" Razzak, Genda Mauza, Savar Paurashava.

4. By law, every enumerator is supposed to visit every house personally during the census survey and mark the home with a visible colour chalk on the entrance to show the home is surveyed. At the end of census survey, I visited an unmarked house, a local resident told me when I asked her whether your family had been counted or not, she told me in reply angrily:

   "Nobody came to my house during census survey, the lazy and dishonest enumerators filled up the census forms sitting in their houses as I heard, they did not bother to visit in this area. Please convey my complaint to the top authority." Fatima, Tatti Mauza, Savar Paurashava.

5. Some enumerators are from the same village, but some of them are not from the concerned village. So they are new to the area. An inexperienced person on his zone complained to me from Ganda Mauza:

   "They did not provide us any sort of map. How can I distinguish the village in mauzas if they are merged together, some mauza names are no longer used by the local people, now they have different village names, how can our authority get quality of information from us if they do not provide us with sufficient information?" Mirza, Bara Oalia, Pathalia Union.

6. In any village, depending on the number of population and size of an area, generally 3-10 enumerators work. But without having clear instruction and lack of coordination, some blocks are counted twice and others not covered at all. An enumerator told me:

   "If we ask local people whether they have inspected already or not, based on their reply we can identify overlapped areas, but for the area which is not covered by any enumerator, how can we know that as there is no enumerator at all?" Bhuiya, Diakhali Mauza, Yearpur Union.

7. Error in counting and filling up the form: There are many problems in filling up the census form, as it is very complicated for illiterate enumerators. They also did not get proper training on how to fill it up correctly. When I pointed out the common mistakes in the forms they filled-up, two enumerators told me separately:

   "The local block supervisor did not inform me in advance about the training date and schedule, so I could not attend the training. That is why I made these mistakes. What can I do when they request to carry on the job without prior knowledge?" Sohel, Akran Mauza, Biralia Union.

   "I could not attend in the training due to *hartals* (general strike)." Sharif, Bara Kakur, Biralia Union.

8. I raised the issue to the Paurashava Chairman and the former MP during his council meeting after the completion of the Census Survey 2001, and he just asked me to verify the issues to the councillors whether they are counted or not. Surprisingly a total of 9 out of 12 answered negatively. Then, one vocal female councillor said:

"As an elected member of the Paurashava Parishad, I am not included, how can we expect the people of my area have been enumerated properly? All the irregularities need a proper and thorough investigation." Rebeka, ward 9, Savar Paurashava member.

Then the paurashava chairman told them to complain about the problems in writing so that he could forward it to the higher authority for necessary action. But it was too late to repair the damage done in the mean time. I also asked a very high ranking BBS officer (anonymous) about the irregularities of the census survey. He did not deny these but hinted that they happened in only a few areas. When he was informed about the problems he took some measures. He went on saying the limited resources and lack of skilled manpower were mainly responsible for that. He mainly focused on the following points as recommendations for the future census surveying:

1. There were no transport arrangements for the census officers and no telecommunication with the Union level officers, so we could not get the updated information about the difficulties at field level;
2. The zone of an enumeration should be smaller in size;
3. The training time should be for an extended period for the enumerators and should be given in intensive form during the training period;
4. To select enumerators, we depend on local Union Parishad Chairman or ward commissioners, but Local representatives do not provide better educated enumerators, they prefer to provide local activists or young musclemen those who are not sincere about their jobs and we cannot replace them;
5. All enumerators and supervisors should be more accountable because we cannot take measures against them if they do not provide expected quality of information;
6. Should be free from all sorts of political influences;

7. Primary school teachers play an important role in the census survey, but they are not accountable to the BBS officers during census survey as they belong to different government bodies;
8. The advertising time at field level was not adequate;
9. Before and immediately after this census survey, the opposition political parties called countrywide hartals, which was unprecedented in Bangladesh. How can we mobilise our resources under this situation. We could not distribute our materials and could not conduct training on time. They should be more respectful of the long-term benefit of the country;
10. Concerned upazila administrations do not cooperate with their resources as there are no guidelines from the central government;
11. The local representative do not like to participate actively unless their interests are served;
12. There are no large-scale settlement (including village and para names with their boundaries) maps in the upazila or Union Parishad. How could we guide (supervisors and enumerators) them and plan the area with the help of mauza names only? A guided map is a must for each Upazila Statistical Officer (responsible for census form 8) at upazila level; zonal officer (responsible for form 7) at Union level or block supervisor (responsible for form 6) at mauza level;
13. In surrounding upazilas of Dhaka city, the zonal officers are deployed from Dhaka head office, but they do not respect the upazila statistical officers (USO) despite status of the USO being higher than the Head office staff in conducting census survey. They do not coordinate with USO at all. How can we expect people from other organisation will help us while we do not help each other?
14. The census forms were not bound this time. This was responsible for the loss or displacement a lot of valuable forms during the carrying, storage, sorting and counting of population data.
15. The provided information regarding mauza and village names is not updated, and some of them are missing.
16. Census forms are complicated to understand for the semi-skilled enumerators.

In August 2001, at a press conference, the government acknowledged that about the 5 percent total population have not been counted in the country during the census survey in January. So they adjusted the total national census database 2001 according to their acknowledgement. This means in Bangladesh that some areas have more or less error than the average inaccuracy. In this predicted context to understand the situation of Savar upazila, we did a complete survey of four sampled mauzas (15 villages) to see how many people are not included at all during the enumeration. We got about 7 percent of the total population less than the counted figures. So in case of Savar upazila we adjusted the total population figure with 7 percent and this error happened due to the above circumstances.

(d) Factors Responsible for Transformations

As we discussed earlier, there are many local factors responsible for the land transformation in the upazila and these have a time dimension. In Table 4-14, the factors are listed and the corresponding unions and years are documented. Here about 30 factors have been identified from the satellite images as accounting for uneven population growth and settlement expansion. Moreover, as an immediate impact of population growth, environmental degradation also occurred in the Union.

Therefore, factors responsible for transformation and any land features visible from space or the air that have been dramatically changed have been documented in this chapter at Union level. These are, among others: bare soil problems as an immediate impact of deforestation; polluted bydes due to industrial effluents and wastes; connected through pucca roads; connections through major bridges; construction of highways; location of famous educational facilities; government dairy farms; presence of a growth centre either ancient or recent; implemented or proposed commercial housing projects; the massive institutional boom; khal network affected due to development activities; expansion of major brickfield belts; concentration of markets and shopping malls; massive government land acquisitions; mega-scale industrialisations and constructions in the EPZ; enormous land acquisitions for housing projects; areas that have frequently suffered deep flooding; the benefits of municipal establishments; gradual expansion around the national monument; disappearance of traditional and valuable orchards; expansion of scattered urbanisation mainly government-funded; the saturation level of some settlement expansions; *shaal* deforestations due to settlement and infrastructural expansion; shifting of river courses; enlargement of Jahangirnagar University; concentration of upazila headquarters; villages deserted due to physical and human factors.

In the Table 4-14, the decade is mentioned when the major changes happened on the land, more specifically, 5 for the early 1950s; 6 for the early 1960s; 7 for the early 1970s; 8 for the early 1980s; 9 for the early 1990s and 0 for the early 2000s. Blank spaces are for either nothing relevant to that category or factors that were not remarkably active.

4.4.0. Conclusion

In this chapter, we have focused on how satellite and aerial images can work with the census database by socialising pixel data. Both census data and remotely sensed can help each other to interpret both data base. From the data, we can gather information and later this information is able to enrich our scientific interpretations.

Here, some examples are cited to recap the context of population census data:

(1) Musurikhola village, which was destroyed and again raised from the riverbed, has not been reflected properly in the census.

(2) The dairy farm has taken in parts of villages, but there is no account in the census the reduction in the mauza area.

(3) Some mauza data are missing in the census and recorded as unpopulated.

(4) Some mauzas are counted where there are no mauzas

(5) Adjacent to Roads and bridges information cannot be taken into account for mauzas;

(6) Physical barriers do not help to increase population e.g. Kandi has no way to expand while chala land can be expanded

(7) Chhota Balimehar mauza shows no population data, but satellite images show a remarkable number of settlements.

However, the entire transformation systems can be classified into two broad categories, natural and human. In brief the subcategories are:

1. Land Transformation by natural activities, e.g.,
    a. Change of River course
    b. Creation of water bodies
    c. Impact of flooding
    d. Natural Population growth
    e. Seasonal variations of inundation
    f. Absolute important of a location
2. Land Transformation by human influence, e.g.,
    a. Land Acquisition
    b. Construction of Roads and bridges
    c. Building infrastructures
    d. Influx of immigrants
    e. Relative important of a location
    f. Introducing chala land agriculture crops using underground irrigations
    g. Deforestation > Orchardisation > deorchardisation

Table 4-14: Summarised Transformation factors and their respected year of events.

Major Incidences or remarkable structural changes or factors responsible for change at Union level	Amin Bazaar	Ashulia	Banagram	Bhakurta	Biralia	Dhamsona	Kaundia	Pathalia	Paurashava	Savar	Simulia	Tetuljhora	Yearpur
Bare Soil problems					9	8							
Bydes polluted						9		7	8	8			
Connected through Pucca Roads		9			9	0		9	8	9	0	9	0
Connecting through Major Bridges	6	9						7			0	9	
Construction of Highways	6	0				9		7	6	6	0	6	0
Famous Educational Facilities								8	5				
Government Dairy Farms								6		6			
Growth Centre: Ancient	5	5							5		5		
Growth Centre: Recent		0				9		7				8	
Housing Projects: Implemented										8			
Housing Projects: Proposed		0				0		0					0
Institutional Boom		0				9		8	7	7			
Khal Network Affected	8	0	9	8									
Major Brickfield Belts	8	0											
Markets and Shopping Malls						0				8			
Massive Govt Land Acquisitions						8		6		6			
Massive Industrialisations and EPZ						9		7	8			9	
Massive land Acquisition for Housing projects		9			0	9		8				8	0
Mostly deeply flooded	5		5	5			5					5	
Municipal Establishments									9				
National Monument Expansion								8					
Orchards disappear		9	0		0	9		9	8				0
Scattered Urbanisation						0		8	9	7			
Settlement Expansions Saturated	7			9			8					0	
Shaal deforestations		5				6		7		6	7		
Shifting of River Courses				5								6	
University Expansion								8		9			
Upazila Headquarters									8				
Villages Deserted		0		6		9		7		6			

Notes for the numeric symbols for the episode year:
5 = early 1950s; **6** = early 1960s; **7** = early 1970s; **8** = early 1980s; **9** = early 1990s; **0** = early 2000s
Blank spaces neither applicable nor remarkable for the particular feature

Savar upazila is passing through a complex transformation process on a very complex undulating deltaic floodplain terrain where every metre of land height is very important. The attraction of land for human habitats has varied over time since 1951 and the current path is moving towards a pro-urban society which may become a reality in a few decades. To see the past and future, the two vast sources of parallel remote sensing and census data can work together to understand the interrelated and interacting phenomena of Savar upazila.

Chapter 5

CHAPTER 5: QUANTIFYING LAND TRANSFORMATION SYSTEMS

5.1.0. Introduction

This chapter is an outcome of the last chapter, but the main focus is to quantify the feature-specific land transformation systems. The reason for mentioning feature-specific census data is that it is highly related with the settlement distribution of the study area. In order to do this, I have used several simple techniques and basic variables of my base data in achieving the goal.

This chapter is a general guideline for detecting and monitoring transformations but the main focus is on population and settlements. The upazila is now part of the Dhaka Capital Development Authority known as Strategic Planning Zone-17, and this means that ultimately the future of Savar will be as a densely urban area in coming decades. In this context, census-settlements are very important to focus on for understanding the process of urbanisation and important for forecasting the spatio-temporal complexities of Savar over time.

In the last chapter I described the factors and context of change but here the changes are quantified in order to understand the level of change over a particular time period. I found it helpful to rank a region (e.g. Savar upazila) at the sub region level (e.g. all Unions of Savar upazila) and this method could be important for policy makers to prioritize decisions in order to fulfil certain development or other relevant objectives. In brief, quantification will be used to understand the land transformation system in detail.

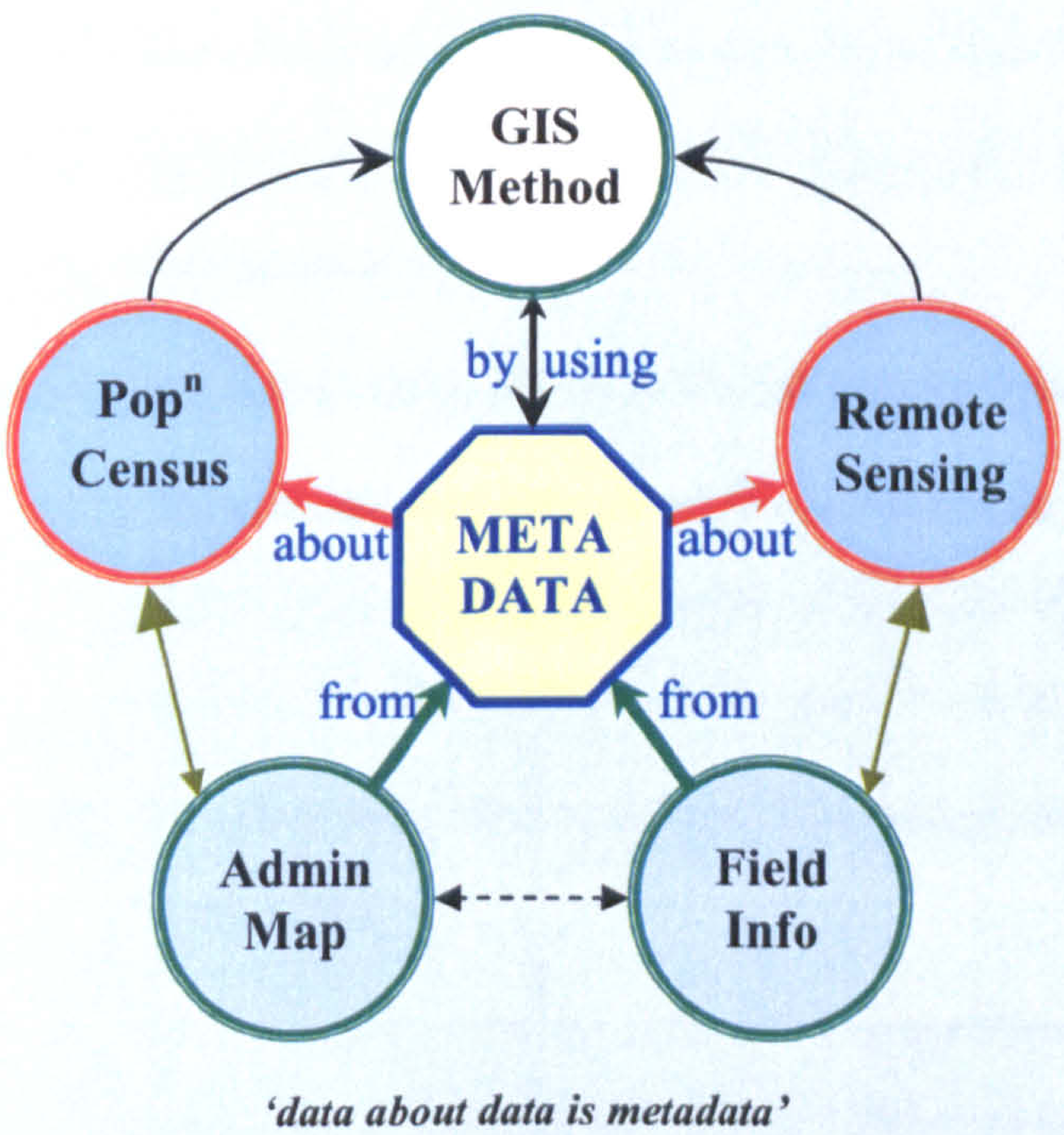
5.2.0. Methodology

(a) Metadata Structure

Metadata or "data about data" describe the content, quality, condition, and other characteristics of data (http://www.fgdc.gov/metadata/metadata.html, 2002). In this research, there are several ways this idea can be explained. Remote sensing data can play a role as metadata for census data, and at the same time census data can also play a similar role for remote sensing data. For the census data, remote sensing can help to explain contexts like land features, while for remote sensing data, population data can add value to land features with an overlay of population characteristics. For both, data collected from the field by interviewing, observation, DGPS surveying and so on can be used as metadata for verifying and interpreting them.

All of the data can be compiled in GIS using different methods of analysis and the GIS may be used to develop data for all of the components, such as, geo-referenced data, area, shape, buffering and so on. Figure 5-1 shows the interrelation amongst all of the major components used in this chapter. The major input from the census is total population in administrative units and from remotely sensed images the settlements and inundation conditions of that administrative unit. Using my own field experience, the GIS databases have been developed from censuses (e.g. traditional population density calculation: area in km^2 from GIS and Population from Census) and images (e.g. adjusted population density: settlement boundaries from remotely sensed images intersected with mauza maps in GIS using calculations fo their area and geographical location with population data). Again field experience helped me to identify and distinguish between highways, *pucca* or *katcha* roads and their names, local land feature names and their importance related to floodibility, factors responsible for changing and developing particular features like EPZ

(Export Processing Zone), and so on. In all cases, metadata has been used for integrating the databases and establishing relationships amongst all of the concerned fields.



Decennial Population Censuses
Population of Unions (1951-2001)
Geocode of Administrative Units
Decennial Population Growths etc.

Decadal Remote Sensing Images
Settlement boundaries (1951-2001)
Land types, Road network
Inundation conditions etc.

Field Data and Information (2001)
Interviewing Key Informants
DGPS survey data,
Still & Motion Pictures etc.

Administrative and Revenue Maps
Upazila Map at Mauza Level
Mauza Map at Plot Level
Geocode and *Daag* N°. etc.

GIS Methods and Attributes
Area and Shape of Features
Geo-referencing of Geo-codes
Geo-processing & Buffering etc.

Source: Formulated by the author, 2002

Figure 5-1: This schematic radial diagram illustrates the multifaceted interrelations of metadata with population census and remote sensing and the role of GIS as a bridge and for communicating with each other in the current research context. In the right side text, some examples of each source of data and images have been elaborated for understanding the nature of attribute features.

The metadata developed using the above approaches and the source data-images are the bases for the following spatio-temporal transformation index analysis.

(b) Calculation Spatio-temporal Transformation Index (ST Index)

For this research relevant to change analysis, a new approach will be introduced using both metadata and source data-images for understanding land transformation systems of Savar upazila using census and remotely sensed data. By using this method, we can determine:

- The rate of change of the particular feature or phenomenon;

- It can be used from the base year or at a particular interval of time (e.g. inter-censual);
- The output can be explained using context analysis of a census;
- The concentration of development can also be evaluated (for example 2001 data);
- Backward regions also can be identified to overcome their limitations and manage their resources;
- The future focus of land use can also be monitored;
- The rate of change is not only dependent on the sub-region (e.g. union), it is highly linked with the overall change of the concerned region (e.g. upazila), so the output reflects the relative change for particular land or population features;
- This will help with mapping the proportionate interdependent progress of certain phenomena;
- The ST index does not only gives quantitative output, but also indicates underlying qualitative factors responsible for the transformation.
- The standard deviations of the IT indexes (of all unions, for instance) illustrate disparity amongst the sub-regions for that particular year.

(c) Definitions of ST Indexes

I calculated ST indexes for the following cases to understand the land transformation system of Savar upazila at the union level:

1. **ST Index for Traditional Population Density**: based on the traditional way of calculating population density. It is a very crude method and planners should in my view not use this parameter for policy implementations, because the outcome is sometimes misleading if the complexities of land features are not considered, in this case no remotely sensed data are required;
2. **ST Index for Settlement Density:** Based only on the territory occupied by settlements in certain years, where no other land complexities have been considered. The method

is very suitable for the study of settlement expansion in the given time limit, and in this case no population census data are required;

3. **ST Index** for **Occupied Population Density:** Based on mixture of the above both techniques to understand the transformation complexities, the technique is highly suitable for understanding existing levels of change and it identifies the most focused region under human settlement of the given period. Here both census and settlement data are required; and

4. **ST Index** for **Adjusted Population Density:** This is the most important ST index, which indicates also the potential power of change for settlement expansion even without knowing the factors responsible for change, and allows the strength of change of a certain region to be understood. The densities of population have been calculated based on the actual flood-free land like *Chalas*, *Dias* and *Kandis*. In any floodplain territories such as in Bangladesh, this could be a major break through in land transformation system analysis, requiring in this case both census data and flood-free lands 'already occupied by settlements and the area left suitable for further expansion of settlements'.

The above first technique can be calculated from census reports and GIS data, but the other techniques are highly dependent on the remotely sensed images and interpretation skills. Table 5-1 is an ideal example for the expected output for the above techniques based on IRS 2000 and the census of 2001.

Table 5-1: The basic data involved in the Spatio-temporal change detection are shown as examples

	Parameters for 2001	Data
Basic Data	Total Dhamsona Union Area (km^2)	33.13
	Total Flood free land left, suitable for settlements expansion (km^2)	23.02
	Settlement Area occupied in 2001 (km^2)*	7.39
	Total Population	98,764
Sample Outputs:	Traditional Population Density (per km^2)	2,981
	Occupied Population Density (per km^2)	13,365
	Adjusted Population Density (per km^2)	4,290
*Note: The data is also consider as basic data and also output data		

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

In Savar, most of the changes have happened due to the land acquisition strategy in the 1960s and recent government policy to establish national institutions and processing zones. It happed mostly in the northern regions. But in the southern region, change was natural where local and nearby physiographic factors were the controlling variables.

The details of change will be elaborated in the relevant section of this chapter case by case. The main benefit will be the use of these ST methods for so many applications of one geographic area, for example, changes in flood prone areas, any change of agricultural activities, the rate of environmental degradation, and the most afflicted areas due to natural calamities.

(d) Inter-decennial Change

To understand the change, generally inter-censual methods have been used for indicating spatio-temporal changes. In the present case study from 1951 to 2001, five indexes can be calculated for understanding land transformation systems. These are: 1951-1961, 1961-1974, 1974-1981, 1981-1991, and 1991-2001 for a certain union or region. However, land transformation during 1951-1961 will be referred to as the 'pre-development' phase while 1991-2001 will be termed as the 'developing' phase of a union. The intermediate time 1961-1981 can be classified as the transitional phase. 1951 will at times be referred to as the 'base year'.

Caution about the 1974 census data:

In general the quality of census data is always a problem in developing countries like Bangladesh. As I have mentioned several times, the census data of 1974 is the worst example in the region. Mainly the *Paurashava*, Savar and Yearpur unions were poorly enumerated. This is why the ST calculation relevant to 1974 census year has to be considered with caution, especially, the ST indexes based on 1961-1974, 1974-1981 and 1951-1974.

On the basis of above discussion, compact formulas can now be presented in order to understand the scenarios of the calculations.

(e) Formulas Involved

As mentioned above, there are several things to be considered during further analysis. Metadata have been developed for assisting and interpolation of population census data. So census, GIS and remote sensing fields were considered together in these circumstances. The details are given in Table 5-2.

Table 5-2: Roles of census reports, GIS and remote sensing images for various methods of Spatio-temporal Transformation Analysis,

Fields	**Census**	**GIS**	**Remote Sensing**		
Parameters	Population (1951-2001)	Building Metadata	Identifying of Flood Free Land left	Identifying of Settlement Areas	Identifying of Flood Prone Areas
Duration	Variable: 1951-2001	Both constant and variable	Variable: 1951-2001	Variable: 1951-2001	Mainly constant
Implications or importance in brief	Total number of population for each census year at unions and upazila units levels	For identified RS features; digitisation and area (in km^2) calculation at administrative units level	Suitable for settlements; road constructions and infrastructural developments	Already occupied by human population and no scope for further expansion	Not suitable for urban settlements as flood risk is very high
Traditional ST	X	X	X	X	X
Settlement ST		X		X	
Occupied ST	X	X		X	
Adjusted ST	X	X	X	X	

Note: X-signs indicate that the relevant values of parameters are considered during calculations, mainly for settlement expansions.

Source: author, 2002

Based on Table 5-2, the following formulae will be used for the calculation of ST indexes. As an example, spatio-temporal transformations during 1951-1961 has been illustrated for different methods, but, the formulae can be used for other inter-censual and base year calculations. The methods of calculation are not complicated but give a meaningful understanding of the underlying complexity. The term 'variable' means that total figure change over time, for example, population of 1951 and 2001 is not the same in an area. The term 'constant' means that the area of land was stable, for example, total area of *chala* land did not change. In the floodplain the total area of *kanda* land does change, due to devastating river bank shifting. As a result the total area of a particular land feature can be constant or variable.

1. **Spatiotemporal Transformation Index for Traditional Population Density:**

$$= \frac{\text{Population Density (PD) of 1951 in a Union}}{\text{PD of 1951 in the Upazila}} + \frac{\text{PD of 1961 in a Union}}{\text{PD of 1961 in the Upazila}}$$

Here, total area in km^2 includes FF (flood-free), FP (flood-prone) and SM (land occupied and populated by settlements) to calculate the population density (PD) per km^2.

2. **Spatiotemporal Transformation Index for Settlement Density:**

$$= \frac{\text{Settlement Area (SA) Extent in 1951 in a Union}}{\text{SA Extent in 1951 in the Upazila}} + \frac{\text{SA Extent in 1961 in a Union}}{\text{SA Extent in 1961 in the Upazila}}$$

Settlement areas in km^2 have been digitised from the remotely sensed images and calculated at union and upazila level using GIS approaches.

3. **ST Index for Occupied Population Density:**

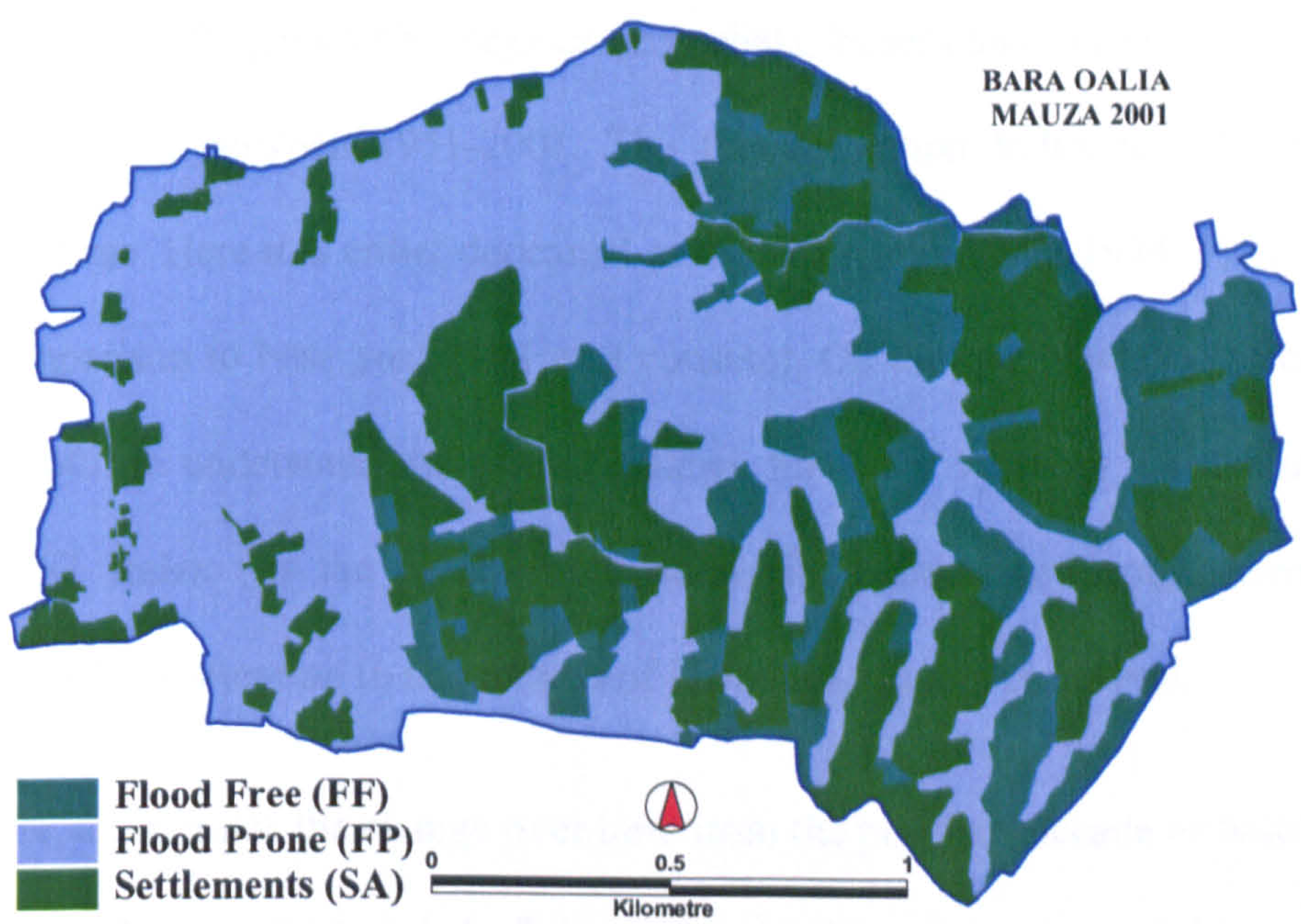
$$= \frac{\text{PD within the settlement area (SA) of 1951 in a Union}}{\text{PD within the SA of 1951 in the Upazila}} + \frac{\text{PD within the SA of 1961 in a Union}}{\text{PD within the SA of 1961 in the Upazila}}$$

Here, population density has been calculated based on only total settlement areas rather than total area of a union or upazila and total population of the union/upazila of the respective year. This excludes FP and FF land as shown in the Figure 5-2. The method indicates the level of saturation of the population density.

4. **ST Index for Adjusted Population Density:**

$$= \frac{\text{PD in 1951 of a Union excluding FP areas}}{\text{PD in 1951 of the Upazila excluding FP}} \div \frac{\text{PD in 1961 of a Union excluding FP}}{\text{PD in 1961 of the Upazila excluding FP}}$$

Here, population density has been calculated based on total FF and SA areas, which exclude FP areas only with the help of the total population mentioned in the census report of a particular year. FF land is the most attractive land for settlement expansion when the other factors are in favour of it. So unions which have no FF land left have no way to expand, but in some unions, there are significant amounts of land still unpopulated and under a suitable environment, therefore, in future these may be explored for the construction of new urban or rural settlements.



Source: mapped based on GIS-RS data, 2002

Figure 5-2: For quantifying land transformation changes over time, the land in Savar upazila can be classified as flood free land (FF), flood prone (FP) and settlement areas in 2001 on the flood free land (SA). Here, FF land indicates the high land (in particular) not currently occupied by settlements.

(f) Importance of Inundation Conditions

Floods are the most influential factor for settlement expansion in Bangladesh. The above map (Figure 5-2), for example, distinguishes the flood prone (FP) areas, flood free (FF) areas and settlement areas (SA). In general, settlements shown are on flood free land but the scope for horizontal expansion is limited. FF land could also be termed as suitable for settlements (SS). This flood free land is mainly chalas, chwaks or kanda lands. But flood prone areas inundate each year by deep or shallow flooding depending on the land types. These flood prone areas are known as bydes, chwaks, beels, rivers or chars.

(g) Explaining Tabular Examples

Table 5-3 shows how the ST index has been calculated from the basic database of population density per km^2 of Savar upazila. Here the term 'spatio' encompasses unions or the upazila or specific geographic regions (e.g. chala, bydes) and 'temporal' refers to the decennial intervals between 1951-2001. The transformation Index reveals the rate of change over time. Here it is either decennial or the change by 1961, 1974, 1981, 1991 and 2001 in comparison to base year 1951 as a constant. On the one hand, the Decennial ST index is helpful to understand the gradual change for every 10 years. On the other hand Base-Year ST Index has the capability to show the fluctuating changes over time in relation to the 1951 situation in the context of Savar upazila at Union level.

For example, to calculate the change over time from the previous decade or base year, two different methods are introduced. In Table 5-3 a database from the population census is presented in MS Excel format. Column A shows the name of unions of Savar upazila and Row 1 the Census Years (1951, 1961, ... and 2001). The corresponding rows (2-14) are the population densities of the each union per km^2. Row 15 calculates the density of population from the total population divided by the total area (284.63 km^2) of entire Savar upazila. Basically this Table reflects the density of population from the raw population and area data.

The data in cells B11, C11, D11, F11 and G11 are the densities of population for Pathalia union of 1951, 1961, 1991 and 2001 respectively. Similarly, B15, C15, D15, F15 and G15 point out the population density of Savar upazila for the same years. On the basis of these references, two tables have been calculated (Table 5-4 and Table 5-5). The equations used were **((D11/C11)/($D$15/$C$15))** and **((G11/F11)/($G$15/$F$15))** for the Decennial ST Index of Pathalia Union during 1961-74 and 1991-2001 to see the decadal change.

Table 5-3: Basic data of Transformation of Population Density (1951-2001): Calculation Method – Pathalia union (columns B, C, F and G) as an example

	A	B	C	D	E	F	G
1	**Union**	**c1951**	**c1961**	**c1974**	**c1981**	**c1991**	**c2001**
2	Kaundia	551	841	991	1540	1853	2631
3	Savar	196	304	8	410	730	1576
4	Amin Bazaar	572	643	849	1229	2379	3017
5	Paurashava	456	595	785	1923	4123	7920
6	Banagram	408	533	586	966	1206	1458
7	Bhakurta	728	824	975	1291	1627	1869
8	Tetuljhora	317	487	658	1011	1385	2186
9	Ashulia	280	346	390	663	805	1665
10	Yearpur	238	296	70	512	598	985
11	Pathalia	**B11**=252	**C11**=356	**D11**=390	923	**F11**=1390	**G11**=2448
12	Biralia	254	333	398	523	623	840
13	Dhamsona	267	365	236	684	1015	2981
14	Simulia	430	510	419	860	1028	1707
15	***Upazila Density***	***B15=356***	***C15=457***	***D15=462***	***885***	***F15=1283***	***G15=2233***

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Table 5-4: Decennial Transformation of Traditional Density (1951-2001): Calculation Method – Pathalia union (1961-1974 and 1991-2001) as an example

Union	**c1951-61**	**c1961-74**	**c1974-81**	**c1981-91**	**c1991-01**
Kaundia	1.19	1.17	0.81	0.83	0.82
Savar	1.21	0.02	28.42	1.23	1.24
Amin Bazar	0.87	1.31	0.75	1.34	0.73
Paurashava	1.02	1.31	1.28	1.48	1.10
Banagram	1.02	1.09	0.86	0.86	0.69
Bhakurta	0.88	1.17	0.69	0.87	0.66
Tetuljhora	1.20	1.34	0.80	0.95	0.91
Ashulia	0.96	1.11	0.89	0.84	1.19
Yearpur	0.97	0.24	3.80	0.81	0.95
Pathalia	1.10	**((D11/C11)/(*$D$15/$C$15*))** =1.08	1.23	1.04	**((G11/F11)/(*$G$15/$F$15*))** =1.01
Biralia	1.02	1.18	0.69	0.82	0.78
Dhamsona	1.06	0.64	1.51	1.02	1.69
Simulia	0.92	0.81	1.07	0.82	0.95

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Table 5-5: Base Year (1951) Transformation of Density (1951-2001): Calculation Method – Pathalia union (1951-1974 and 1951-2001) as an example

Union	c1951-61	c1951-74	c1951-81	c1951-91	c1951-01
Kaundia	1.19	1.39	1.12	0.93	0.76
Savar	1.21	0.03	0.84	1.04	1.28
Amin Bazar	0.87	1.14	0.86	1.15	0.84
Paurashava	1.02	1.33	1.69	2.51	2.77
Banagram	1.02	1.11	0.95	0.82	0.57
Bhakurta	0.88	1.03	0.71	0.62	0.41
Tetuljhora	1.20	1.60	1.28	1.21	1.10
Ashulia	0.96	1.07	0.95	0.80	0.95
Yearpur	0.97	0.23	0.86	0.70	0.66
Pathalia	1.10	((D11/B11)/($D$15/$B$15)) =1.19	1.47	1.53	((G11/B11)/($G$15/$B$15)) =1.55
Biralia	1.02	1.21	0.83	0.68	0.53
Dhamsona	1.06	0.68	1.03	1.05	1.78
Simulia	0.92	0.75	0.80	0.66	0.63

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

(h) The meaning of ST Indicators

Table 5.6 shows the key tool for understanding the meaning of the results calculated by the ST index formulas. The average is 1 and the result can be more than or less than 1. The ultimate change that happened in a particular decade or a time period of an upazila is always 1 and the unions belonging to this upazila have several probabilities as mentioned in Table 5-6.

Table 5-6: The explanation of ST Index results calculated from the raw data

IT Index	Interpretation keys in terms of transformation
= 1	The average transformation rate, for the upazila and the union are the same; parallel or similar rate of transformation;
< 1	The transformation rate of a particular union is less than the corresponding upazila; rapid
> 1	The transformation rate of a particular union is more than the corresponding upazila;
= 0	Landmass destroyed due to riverbank shifting or massive land acquisitions, or possibly due to missing census data, where the tendency of change is always very close to 0. It may also result from the inverse effect in some areas as a consequence of rapid expansion elsewhere;
> 2	The change is more than twice as fast as the average progression rate;
range	The two or more year ST indices indicate the rate of change over time in a certain region or union for a certain feature, for example, the area occupied by settlements.

Source: Author, 2002

These techniques can be applied to population change on or relevant to a particular feature of land cover or land use and water bodies. In this chapter I have introduced this one to understand the population change based on census data and territories covered by the settlements based on high resolution remotely sensed decadal data.

To explain the above interpretation key, Table 5-7 is one of the most significant databases for Savar upazila for understanding the process of urbanisation and to indicate the importance of some unions in agricultural sectors in the context of seasonal inundations. In this Table, the total area has been considered instead of base year data, to understand the background of the union in the 2001 context. Here, unlike inter-censual calculations, no temporal change has been considered. All of the databases are related to the latest information.

<0.25	0.50	0.75	1.00	1.25	1.50	1.75<
Least Potential			**Average Potential**			**High Potential**
Negligible Change			**Balanced Change**			**Remarkable Change**

Figure 5-3: Interpretation keys as shown in numeric for the ST indexes for understanding relative change for a particular land feature. Here balanced change means that the change is relatively similar in a particular sub-region (e.g. Union) to overall change for the region (e.g. upazila).

Using the above interpretation techniques (Figure 5-3), the following comments can be made based on Table 5-7. In this table, column H is the outcome from the column C, which contains the land occupied in a union by settlements in 2001. Savar Paurashava has a 3.60 ST index which means that if we consider only the landmass for change detection, it has the most potential land for settlements while with showing a 0.18 value, Amin Bazaar is in the worst situation as there is no ground for expansion. In column D, the data shows how much land can be utilised for urban expansion or developing infrastructures on flood free land which is still not yet occupied by settlement and remains in high land agricultural activities or is still considered as open space or used for backyard orchards. It is to be noted that the rate of massive population change suggests there will not be any agricultural activities left in a few decades. The capital Dhaka has already passed this stage in the last three decades.

Table 5-7: Flooding statistics in context of settlement expansion in 2001 of Savar Upazila.

Union	Area Km^2	Occupied by Settlements	Flood-free Land left	Flood Risk Land	Spatial Index for C	Spatial Index for D	Spatial Index for E
A	B	C	D	E	H	F	G
Kaundia	7.78	0.58	0.03	7.17	0.33	0.01	1.87
Savar	10.76	2.10	*7.00	1.66	0.85	2.33	0.31
Amin Bazaar	10.99	0.46	0.10	10.43	0.18	0.03	1.93
Paurashava	16.72	13.76	1.20	1.76	3.60	0.26	0.21
Banagram	17.28	3.37	2.10	11.81	0.85	0.43	1.39
Bhakurta	20.35	2.52	0.09	17.74	0.54	0.02	1.77
Tetuljhora	20.65	2.35	0.50	17.80	0.50	0.09	1.75
Ashulia	26.30	7.38	14.00	4.92	1.23	1.90	0.38
Yearpur	27.44	5.65	9.77	12.02	0.90	1.27	0.89
Pathalia	28.45	5.72	*9.59	13.14	0.88	1.20	0.94
Biralia	29.66	6.96	10.72	11.98	1.03	1.29	0.82
Dhamsona	33.13	7.39	15.63	10.11	0.98	1.69	0.62
Simulia	35.12	6.85	8.90	19.37	0.85	0.91	1.12
Upazila (Km^2)	**284.63**	**65.09**	**79.63**	**139.91**	*****1.00***	*****1.00***	*****1.00***

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Notes:

C = Occupied by Settlements in 2001

D = Flood-free Land Left for Future Urbanisation

E = Flood Risk Land (Mainly for Agriculture)

F = Flood free Land Left (Ideal for future Settlement expansion, * = most important column)

G = Flood Risk Zone (the land flooded annually, mainly suitable for Agriculture)

H = Existing Land Occupied by Settlements (in 2001)

* = The land mostly occupied by government acquisition where only government policy can trigger the change of land transformations, for example expansion of University Infrastructures; non-* areas mostly depend on private initiatives, but government guidelines are essential.

** = 1 denotes the average value of change in the upazila. In the column, more than 1 indicates that the potentiality of change is more the average; the higher value indicate the higher chance of change. Less than 1 indicates a lower probability of change than the upazila average, the minimum value the least chance.

Savar faces an increasing urban future since RAJUK expanded its territory by engulfing the upazila in 1997. But its flood-free lands are not necessarily the most lucrative areas in the entire RAJUK zone. Savar Union (2.33), Ashulia Union (1.90), Dhamsona Union (1.69) have the highest scores in column F. These unions have the most potential highlands. But in the cases of Kaundia (0.01), Bhakurta (0.02), and Amin Bazaar (0.03) unions, there is no hope for immediate urban or relevant infrastructural development or expansion.

The remaining lands are highly vulnerable to annual flooding. Column G shows the inverse to columns H and F. The highest scored unions are risky zones for flooding. But they can be seen as positive for agricultural expansion. In these cases of Amin Bazaar (1.93), Kaundia (1.87), Bhakurta (1.77), Tetuljhora (1.75) this is especially true. In the case of Amin Bazaar, due to locational advantages the conflict between dry season agriculture and brick field are visible. Brickfields are found here as they are highly profitable in terms of transport and labour costs. That is why except for Amin Bazaar Union, unions which scored more than one are mostly suitable for Rabi crops. So policy-makers should reserve this union for agricultural activities. The Paurashava, Savar Union, and Ashulia can not play a significant role in the agricultural sector. For the sustainable development of agricultural activities the government must ensure that the byde lands are not polluted due to industrial and urban expansion on the nearby chala or flood-free highlands. So for agricultural policy makers, column G is more significant, though this research is not intended to focus on that.

5.3.0. Issues Involving ST Index

The following indices can be calculated using GIS and remote sensing methods to monitor land transformation systems in several realistic ways. Particularly the application of GIS has opened the gate for the following spatial values. The various settlements identified have been digitised using the image interpretation techniques mentioned in chapter 4. The data developed here can be defined as metadata for the census data. Since there is no supporting database available in the census reports, this metadata can play a significant role for policy makers and planners. The techniques introduced here will also show academic colleagues how census and satellite (as well Aerial Photos) sources can work together in an integrated form to achieve a common goal. Several types of density can be calculated other than in traditional ways. All of them have advantages and disadvantages. But the use of metadata at the mauza or union level is the most significant application in this chapter.

(a) Population Density

This database is the most common and traditional for geographical or social applications. The data is calculated from the total area and total population of an administrative unit. The general Population density tables have been placed in the previous chapter.

(b) Settlement Density

Table 5.8 has been calculated from the decennial remote sensing images. There is no use of census data here. All data are shown in km^2. The last row is the total settlement area of Savar upazila. All 1951 to 2001 datasets are found here. For example, in 1951 total area covered by the settlements was 35.56 km^2 and in 2001 it had increased to 65.09 km^2. But the settlement expansion rate was not similar at union levels, the following Table 5-8 gives the details at union level.

Table 5-8: The area covered by settlements in Savar Upazila.

Union	c1951	c1961	c1974	c1981	c1991	c2001
Kaundia	0.43	0.45	0.46	0.51	0.52	0.58
Savar	0.90	0.50	0.70	1.10	1.30	2.40
Amin Bazaar	0.34	0.35	0.39	0.43	0.45	0.46
Paurashava	5.75	6.28	6.38	6.41	8.03	13.46
Banagram	2.21	2.24	2.60	2.80	3.01	3.37
Bhakurta	1.46	1.33	1.31	2.03	2.41	2.52
Tetuljhora	1.41	1.53	1.65	1.74	1.95	2.35
Ashulia	4.26	3.95	4.25	5.10	5.61	7.38
Yearpur	2.63	2.65	2.65	2.87	3.51	5.65
Pathalia	4.25	3.38	4.10	4.23	4.41	5.72
Biralia	5.29	5.31	4.98	5.73	6.21	6.96
Dhamsona	2.77	2.81	3.20	3.54	4.43	7.39
Simulia	3.86	3.92	4.12	4.65	5.09	6.85
Total	**35.56**	**34.70**	**36.79**	**41.14**	**46.93**	**65.09**

Source: Calculated from GIS-RS data, 2002

(c) Occupied Population Density

Table 5-9 shows the population density only for the area occupied by buildings. Bhakurta union is 20.34 km^2, but all of these areas are not under occupation of human settlements and infrastructures. To understand the real density of that union, I considered the populated areas only for density calculations. Here, on only 2.5 km^2 total inhabitants number 38,025. That means that the density of population on the occupied land was 15,089 in 2001 in comparison to traditional density of 1,869 per km^2 for the same year. For example to establish a school in this area, the occupied density is more important than the traditional way of calculating population density. This method is much more realistic for population intensive planning and the development sector, even to understand the number of victims of flood or at risk of floods in each year.

(d) Adjusted Population Density

This is a slight modification of the density calculation based on the flood free land identified by the satellite or aerial photos. This density reflects the hidden potentiality of land as well. For example, settlements in a low-lying active floodplain delta like Bangladesh are always dependent on the availability of flood free land. Particularly, the study area is very close to the highly populated capital city of Bangladesh. The population flow is now moving towards this area after having new and better road connections with the highlands (mainly chala lands) of Northern Savar upazila.

Table 5-9: Density of population per km^2 on the land occupied by the settlements

Union	c1951	c1961	c1974	c1981	c1991	c2001
Kaundia	9,960	14,540	16,761	23,480	27,719	35,283
Savar	2,339	6,534	116	4,013	6,046	7,065
Amin Bazar	18,491	20,169	23,921	31,393	58,064	72,043
Paurashava	1,327	1,585	2,058	5,017	8,587	9,839
Banagram	3,190	4,112	3,898	5,963	6,924	7,478
Bhakurta	10,144	12,614	15,147	12,936	13,740	15,089
Tetuljhora	4,645	6,571	8,232	11,994	14,663	19,207
Ashulia	1,732	2,307	2,414	3,421	3,773	5,936
Yearpur	2,488	3,060	727	4,897	4,679	4,787
Pathalia	1,689	2,995	2,705	6,207	8,969	12,178
Biralia	1,423	1,860	2,370	2,709	2,976	3,580
Dhamsona	3,199	4,300	2,443	6,405	7,591	13,365
Simulia	3,912	4,568	3,573	6,495	7,094	8,754
Upazila	2,849	3,749	3,572	6,126	7,783	9,764

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

How can we understand the potentially of this land? In this case the total of flood-free land has been considered in order to understand the strength of land for a given time period. The population density can only be based on this land for the further expansion of settlements. For example (Table 5-10), the total high land including current settlement areas in Ashulia Union is 26.30 km^2, the settlement areas occupied was 7.38 km^2 in 2001, the flood free land left is 14 km^2 and the flood prone land is 4.92 km^2. In this calculation, the total change has been considered from the perspective of the highlands. This means that 7.38 km^2 plus 14.0 km^2 land have been chosen for the population density calculation. As a result the real density has been calculated based on the real capacity of land. The land development agencies and the urban monitoring cells of Bangladesh can rely on this and can forecast the future growth and concentration of developments with the study area. The density shows that Amin Bazaar has reached a spill over situation of 59,179 people per km^2. Other unions like Kaundia, Bhakurta, and Tetuljhora have 6 digit density of population. In comparison to that, 5 digit population density unions are carrying expansion potential because they have capacity to accommodate more people as the density is relatively low. All of north eastern unions have potential for further settlement expansions and/or planned urbanisation.

Table 5-10: Adjusted population density per km^2 based on existing and potential land for settlements (excluding only flood prone areas) in the concerned unions

Union	c1951	c1961	c1974	c1981	c1991	c2001
Kaundia	7,021	10,726	12,639	19,631	23,630	33,548
Savar	231	359	9	485	864	1,863
Amin Bazaar	11,227	12,605	16,659	24,105	46,659	59,179
Paurashava	510	665	878	2,150	4,609	8,853
Banagram	1,289	1,684	1,853	3,052	3,810	4,607
Bhakurta	5,674	6,428	7,603	10,061	12,687	14,569
Tetuljhora	2,298	3,527	4,766	7,323	10,032	15,838
Ashulia	345	426	480	816	990	2,049
Yearpur	424	526	125	911	1,065	1,754
Pathalia	469	661	724	1,715	2,584	4,550
Biralia	426	558	667	878	1,045	1,409
Dhamsona	385	525	340	985	1,461	4,290
Simulia	959	1,137	935	1,918	2,293	3,807
Upazila Average	700	899	908	1,741	2,524	4,391

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

5.4.0. Analysis of ST Index

The spatio-temporal index helps to understand and quantify the level of transformation which has occurred for particular features or parameters. In this chapter, I introduce some of the fundamental ideas of how to calculate the decennial changes or inter-decennial changes. Savar upazila has experienced massive change but this change has had time specific concentration over the last half century. The upazila cannot be explained independently as it is the best suitable for settlement expansion as Dhaka has already been saturated by overpopulation. The above table is very important to understand the outcome of the ST indexes. Most of the changes are linked with these phenomena.

(1) *Development Phases*

Under the subtitle of 3 broad phases, the discussion can be categorised. Though all of these classes are currently visible in the upazila, the major take-off stage is evidenced especially by population concentration. Each phase may have been initiated and reached a mature stage but not necessarily abandoned before the arrival of the next phase. Interestingly, the following groups can also be categorised on the basis of general sources of drinking water.

1. **Predevelopment phase (generally until 1961):** In this early phase, the upazila was wholly based on primary economic activity and the economy and transport system were dependent on the rivers or on flood water. There were no pucca roads and national highways at this time. Agricultural, fishing and forestry resources were the main sectors of the local economy. This sort of economy had predominated here for hundreds of years. This was a ***'Surface Water Society'***, as the sources of drinking water were only *pukur*, *doba*, river, or *khal*, and they had no mechanism to withdraw groundwater at this time. All of the land of the upazila was under this category until the early 1960s, though some parts of the upazila still belong to this class.

2. **Developing Phase (generally between 1961 and 1991):** In this time period the major land acquisition happened and most of the road network and bridges were constructed. The establishments of Jahangirnagar University, the National Monument, the German aided dairy farm, Savar Senanibas and various other government and private establishments date from this time. Most of the industrial units also started production during this period. This phase has also been termed the ***'Shallow Tubewell Society'*** as people started drinking ground water. Most of the upazila still belongs to this group.

3. **Urbanisation or Pro-urban Phase (since 1991):** A lot of development work and/or plans for urbanization originated in this time frame, mainly during 1991-2001, among others the RAJUK master plan, the Paurashava declaration and plan initiation, the proposal for Dhamsona Satellite town, the construction of modern shopping complexes, and the establishment/ impact of the Export Processing Zone. The urbanisation phase was embedded in this period. On the acquired lands, many of the establishments have fully flourished or matured. All of the union headquarters and local growth centres were connected by pucca roads at this time. Though the upazila cannot be described simply as an urban area, as there are no urban services in general, the primary step for urbanisation was initiated. It may take two more decades for the development of urban service sectors e.g., a meaningful municipality, flowing tap water, electrification and supply of gas for most of its customers. The population explosion that belongs to this time period represents a take off situation. This phase can also be termed as the ***'Tap Water Society'*** as people are dependent on flowing water from a water tank on the roof; in general deep tubewells are used to draw this water. Only a few areas have been transformed into this stage.

In the following graph (Figure 5-4), we are able to visualise the changes in population statistics during three stages: pre-developed, developing and urbanisation phases. It shows the details of population figures and their gradual change over time. For instance, in 1951, the population of the Paurashava area was 7,631, increasing to 9,951 in 1961. This gradually increased over time and reached 68,952 in 1991. Finally in 2001, the total population has dramatically risen to 132,435. This graph also indicates a comparison between the first and last decades of population change of the studied inter-censual periods.

However, developments or transformations did not happen in all unions at an equal rate. How can we understand the level of change and their differences? In this chapter, population census data are the base information and population-related features on the images are settlements. These two settlement and population databases, have been generated from the source data. Here, four fields of research items are identified as mentioned before:

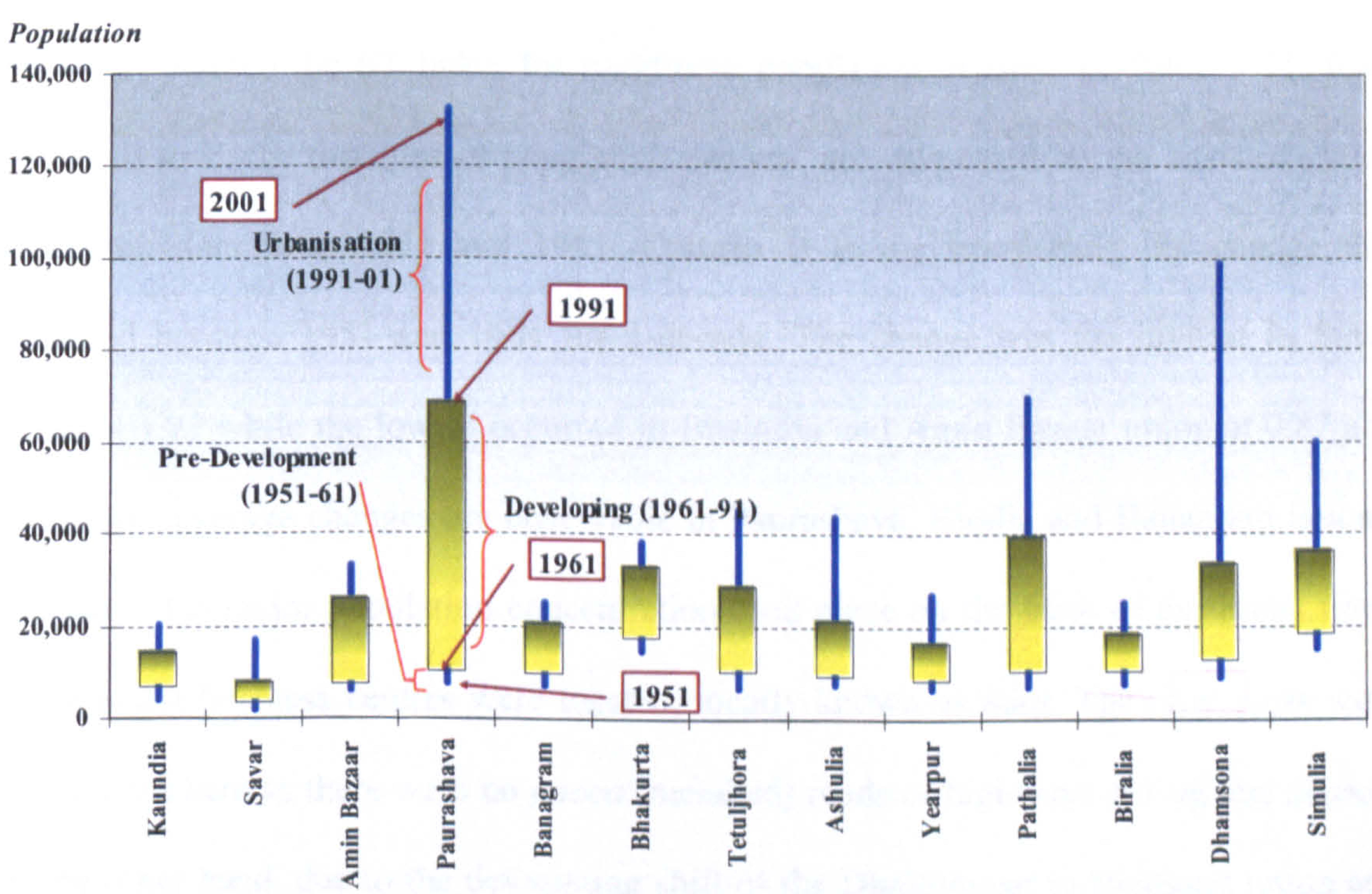
(1) ST Index based on Traditional Population Density;

(2) ST Index based on Settlement Density;

(3) ST Index based on Occupied Population Density; and

(4) ST Index based on Adjusted Population Density:

The details of the each parameter have been discussed below with the detailed outcome of the calculation for the each union of Savar upazila. The first three ST Indexes are presented briefly with data tables and figures. The fourth ST index for the Adjusted Population Density will be elaborated with examples, illustrations and detailed description as this is to be considered most effective for the study area.



Source: Author, 2002

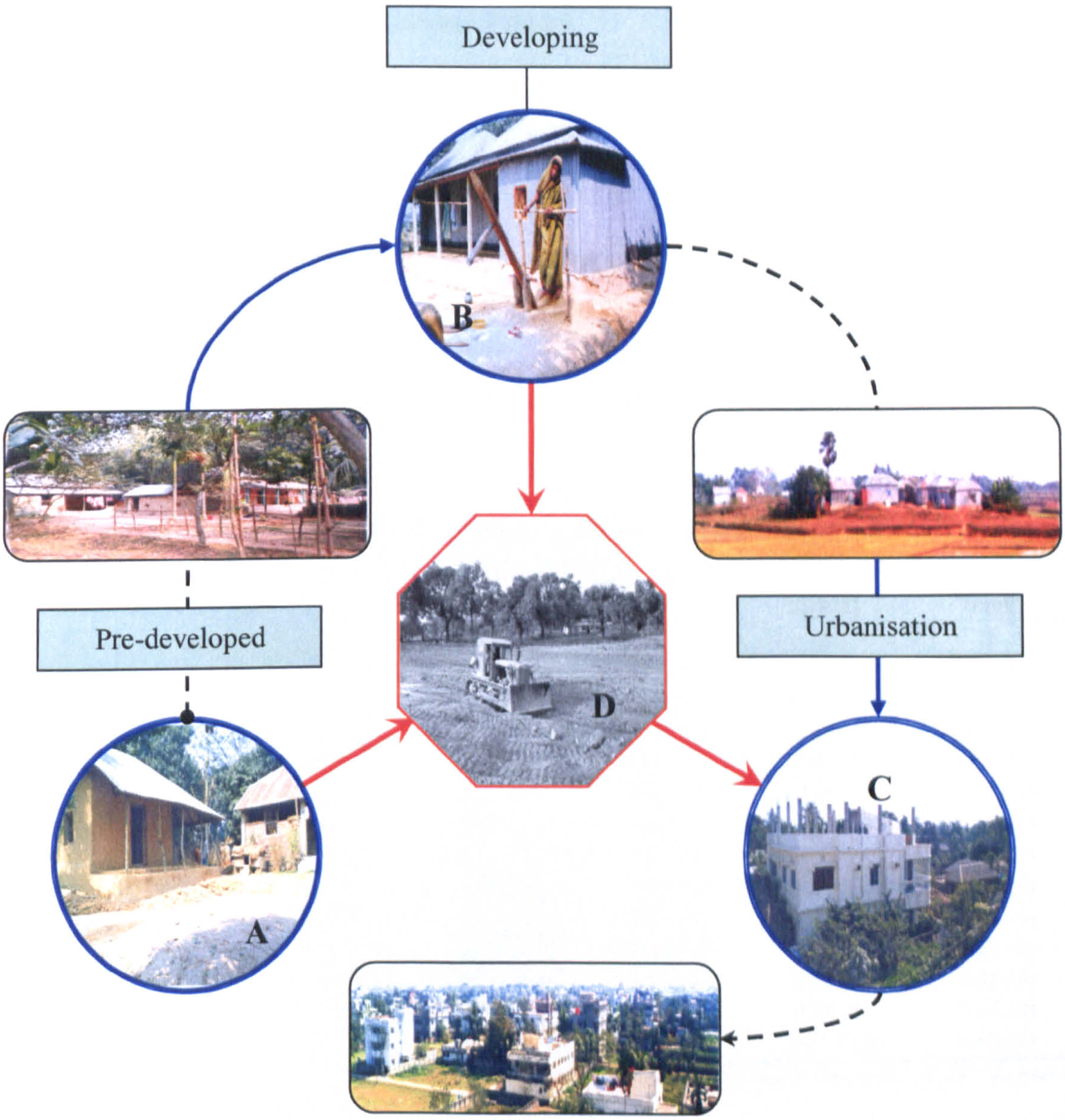
Figure 5-4: Three Phases of progress in terms of total population growth and population strengths at union level have been illustrated here. The bottom blue line (narrow line) is the population change between 1951and 1961 and the top blue line is the 1991-2001 population growth. The middle boxes are the overall change between 1961 and 1991.

(2) *Photographic Evidence of Succession*

Figure 5-5 is based on field photographic evidence of the transformation for settlements and can be linked with the overall pattern of development. The nature of housing and surroundings are unique and are easily identifiable *in situ*. The variety, from mud walls to tinned walls to brick, helps us to understand the complexion of the societies in Savar upazila. In local terms, these clusters of buildings (*graam*) are known as *paara*, *mahalla* and ward respectively.

5.4.1. ST Index based on Traditional Population Density

In general, we calculate the density of population on the basis of the total area of an administrative region and the total population of that area in a certain year. Here, this sort of calculation has been termed as Traditional Population Density. Based on these data, the results are termed the ST index for traditional population density. In Table 5-11, from column B to F, the densities of population per km^2 are calculated on the basis of Union population data from 1951 and 1961. Column B is for interpreting the change that happened between 1951 and 1961 for a decade. The change was the highest in Savar Union at 1.21 while the lowest occurred in Bhakurta and Amin Bazaar union at 0.87 and 0.88. More average changes are observable in Paurashava, Biralia and Banagram unions. Therefore, the major population concentration took place on the bank of the Bansi river, where major business centres were located, locally known as *haat*. The river ports were also located here as there were no *pucca* (metalled) roads or highways during this decade. On the other hand, due to the devastating shift of the Dhaleshwari in Bhakurta union and unsuitability for expansion of Amin Bazaar, these areas were mostly neglected and the least attractive part of the upazila.



Source: Photos are taken during the field visit to Savar, 2001

Figure 5-5: *In situ* settlements transformation using very distinctive photographic evidences in Savar upazila from the societies called *pre-developed* (**A**, from Bara Kakur mauza) to *developing* (**B**, from Banshbari mauza) to the *urbanisation* (**C**, from Ganda mauza) phases. In the circles are examples of sample units of settlement and rectangles illustrate a cluster of settlements that belong to the same class. The arrows indicate the process of land developments over time; and **D** indicates an example of an external power as a land transformation agent.

In 1974, a huge amount of data was missing, resulting in big deviations of population change and the outcome was very unrealistic, especially Savar and Yearpur unions, which are the most troublesome. There is no reliable data for these unions. Due to 1974 data loss, the 1961-1974 and 1974-1981 data were affected.

Figure 5-6 is an example of the traditional way of mapping population distribution at mauza level based on census data in Bangladesh using the upazila administrative base map. To some extent it is misleading, as non-inhabited is shown as part of the population distribution pattern. Missing mauzas show misleading gaps, which were not surveyed during the census enumeration of 2001. Please see Figure 5-13 for a comparison with the adjusted population density map.

Table 5-11: Decennial Transformation using Traditional Population Density (1951 to 2001)

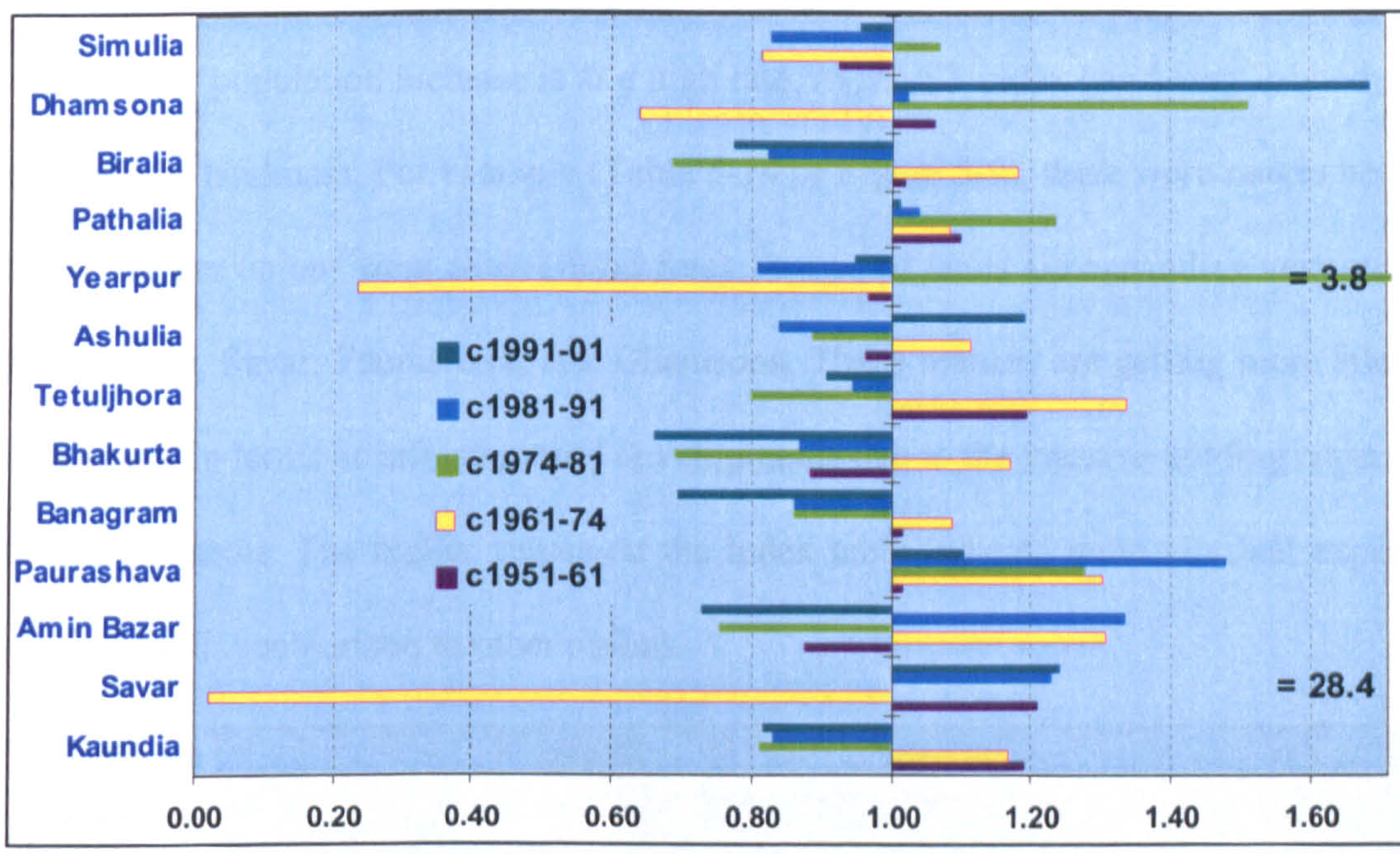
Union	c1951-61 (rank)	c1961-74 (rank)	c1974-81 (rank)	c1981-91 (rank)	c1991-01 (rank)
A	B	C	D	E	F
Amin Bazaar	0.87 (13)	1.31 (3)	0.75 (11)	1.34 (2)	0.73 (11)
Ashulia	0.96 (10)	1.11 (7)	0.89 (7)	0.84 (9)	1.19 (3)
Banagram	1.02 (7)	1.09 (8)	0.86 (8)	0.86 (8)	0.69 (12)
Bhakurta	0.88 (12)	1.17 (6)	0.69 (12)	0.87 (7)	0.66 (13)
Biralia	1.02 (6)	1.18 (4)	0.69 (13)	0.82 (12)	0.78 (10)
Dhamsona	1.06 (5)	0.64 (11)	1.51 (3)	1.02 (5)	**1.69 (1)**
Kaundia	1.19 (3)	1.17 (5)	0.81 (9)	0.83 (10)	0.82 (9)
Pathalia	1.10 (4)	1.08 (9)	1.23 (5)	1.04 (4)	1.01 (5)
Paurashava	1.02 (8)	1.31 (2)	1.28 (4)	**1.48 (1)**	1.10 (4)
Savar	**1.21 (1)**	0.02 (13)	**28.42 (1)**	1.23 (3)	1.24 (2)
Simulia	0.92 (11)	0.81 (10)	1.07 (6)	0.82 (11)	0.95 (6)
Tetuljhora	1.20 (2)	**1.34 (1)**	0.80 (10)	0.95 (6)	0.91 (8)
Yearpur	0.97 (9)	0.24 (12)	3.80 (2)	0.81 (13)	0.95 (7)

Source: Basic data taken from Chapter 4

If we see the graphs (Figures 5-7 and 5-8), the mean value is 1 on the Y-axis and the bars extending to the left and right are the deviation from the mean of the each union. We can visualise the change very clearly. Simulia, Biralia, Yearpur, Bhakurta had negative deviations while Dhamsona (mainly 2001), Pathalia, Tetuljhora and Paurashava have positive deviations. Massive changes appear in the cases of the Paurashava and Pathalia union. Using the base year 1951 calculations, the Paurashava demonstrates massive changes over the last 50 years.

However, in this method, there is no role for remote sensing images to help understand the landmass changes in the inter-censual periods, and this method does not show the expansion of the populated landmass or the change in landmass over time.

In the next example, we will focus on settlement expansion, which may help to understand more about the physical land transformation rather than population change.



Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

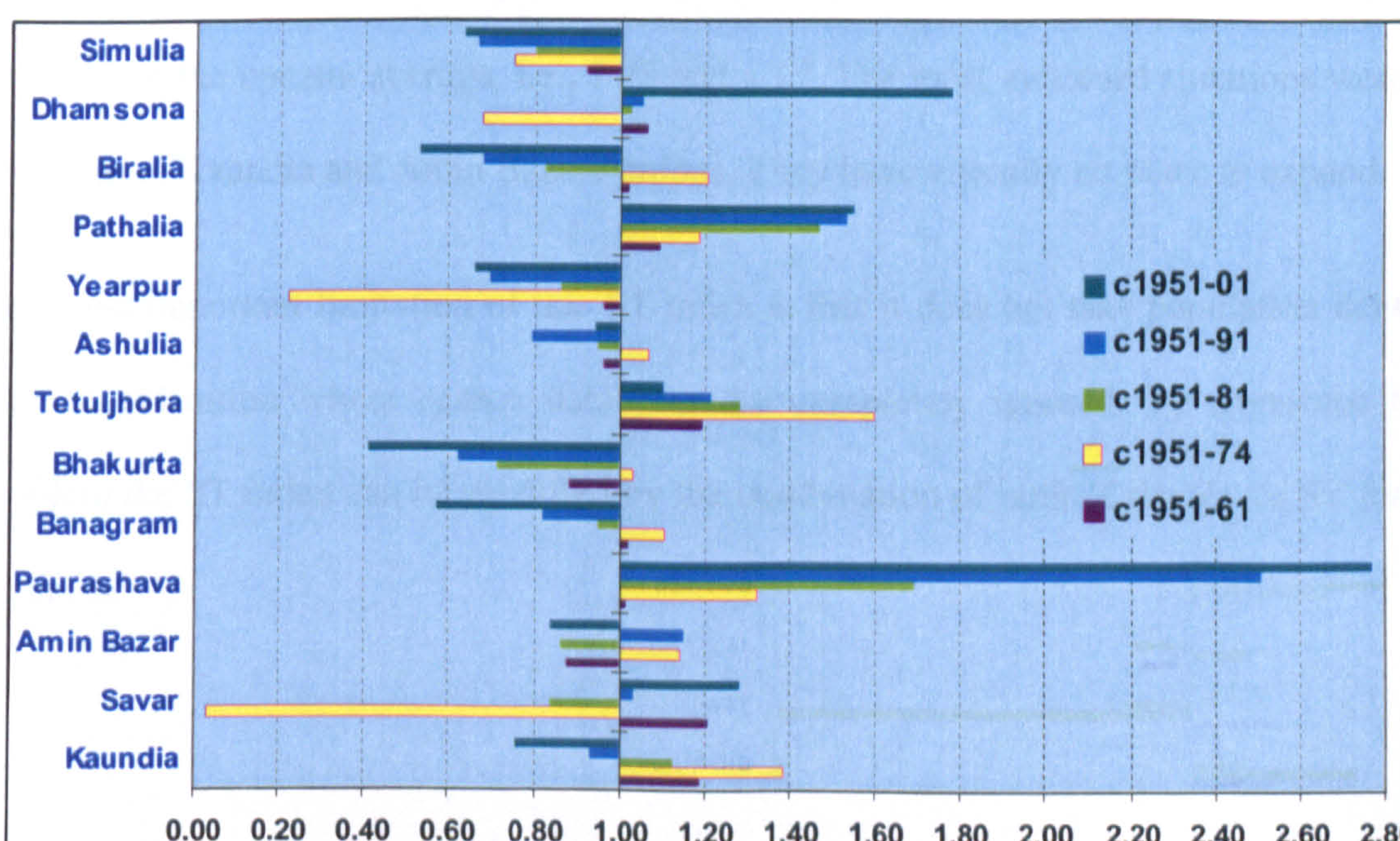
Figure 5-7: Population Change Index (1951-2001): Inter Censual /Decennial transform

In Table 5-12, the same base data have been used, but instead of an inter-censual computation, the 1951 base year has been fixed.

5.4.2. ST Index based on Settlement Territories

To overcome the limitation about settlements, relevant data was based on remote sensing images, and the total area calculated in km^2 using GIS techniques. Table 5-13 shows this database for further analysis. The ST index for the study of settlement change has a very strong link with the population census. The maps (Figure 4-12 in the previous chapter and

Figure 5-13) show the density of population in the enclosed settlement zones at mauza level. This can be used fruitfully for change detection monitoring. The total area covered by the settlements is increasing steadily. The area covered in 1951 was 36 km^2 and 65 km^2 in 2001, but some unions have more suitable land for expansion than others, so the expansion of settlements has not occurred homogeneously. Some unions have much better flood-free land. For example, Kaundia, Amin Bazaar and Bhakurta have very limited land, though their population increase is at a high rate, so the ST index has a very limited scope to show the landmass. For example (Table 5-14 or Figure 5-9), there were ranges between 0.7-0.8 where unions were chala (flood-free) dominated lands are expanding very quickly, for example, Savar, Paurashava, and Dhamsona. These mauzas are getting more attention than others in terms of infrastructural developments due to the massive holding capacity of their settlements. The higher values on the index table indicate more physical expansion on the land in comparison to other unions.



Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Figure 5-8: Population Change Index (1951-2001): Base year 1951 (cumulative transform)

Table 5-12: Transformation of Population Density, 1951 as a base year

Union	c1951-61	c1951-74	c1951-81	c1951-91	c1951-01	Rank
Amin Bazaar	0.87	1.14	0.86	1.15	0.84	7
Ashulia	0.96	1.07	0.95	0.80	0.95	6
Banagram	1.02	1.11	0.95	0.82	0.57	11
Bhakurta	0.88	1.03	0.71	0.62	0.41	13
Biralia	1.02	1.21	0.83	0.68	0.53	12
Dhamsona	1.06	0.68	1.03	1.05	1.78	2
Kaundia	1.19	1.39	1.12	0.93	0.76	8
Pathalia	1.10	1.19	1.47	1.53	1.55	3
Paurashava	1.02	1.33	1.69	2.51	2.77	1
Savar	1.21	0.03	0.84	1.04	1.28	4
Simulia	0.92	0.75	0.80	0.66	0.63	10
Tetuljhora	1.20	1.60	1.28	1.21	1.10	5
Yearpur	0.97	0.23	0.86	0.70	0.66	9

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

In the base-year index (Table 5-15 or Figure 5-10), the four mauzas reflect the most significant change in comparison to the 1951 context. This is reflected in the visible change that has happened in these unions. For instance, Savar and Dhamsona had similar changes during the 1951-2001 period of 1.46, and *Paurashava* and Yearpur had slightly higher than the upazila average, i.e., 1.28 and 1.17. The most awkward situations were in the cases of Kaundia and Amin Bazaar unions. They have virtually no place to expand.

The most important limitation of this ST index is that it does not take population density into consideration where census databases are completely ignored. To overcome this problem the ST index can be modified by the combination of both of the above ST Index methods.

Table 5-13: Settlement Expansion over 1951-2001 at decadal intervals (km^2)

Union	c1951	c1961	c1974	c1981	C1991	c2001
Kaundia	0.43	0.45	0.46	0.51	0.52	0.58
Savar	0.90	0.50	0.70	1.10	1.30	2.40
Amin Bazar	0.34	0.35	0.39	0.43	0.45	0.46
Paurashava	5.75	6.28	6.38	6.41	8.03	13.46
Banagram	2.21	2.24	2.60	2.80	3.01	3.37
Bhakurta	1.46	1.33	1.31	2.03	2.41	2.52
Tetuljhora	1.41	1.53	1.65	1.74	1.95	2.35
Ashulia	4.26	3.95	4.25	5.10	5.61	7.38
Yearpur	2.63	2.65	2.65	2.87	3.51	5.65
Pathalia	4.25	3.38	4.10	4.23	4.41	5.72
Biralia	5.29	5.31	4.98	5.73	6.21	6.96
Dhamsona	2.77	2.81	3.20	3.54	4.43	7.39
Simulia	3.86	3.92	4.12	4.65	5.09	6.85
Total (Km^2)	**35.56**	**34.70**	**36.79**	**41.14**	**46.93**	**65.09**

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Table 5-14: Decennial Transformation of Settlement Density (1951-2001)

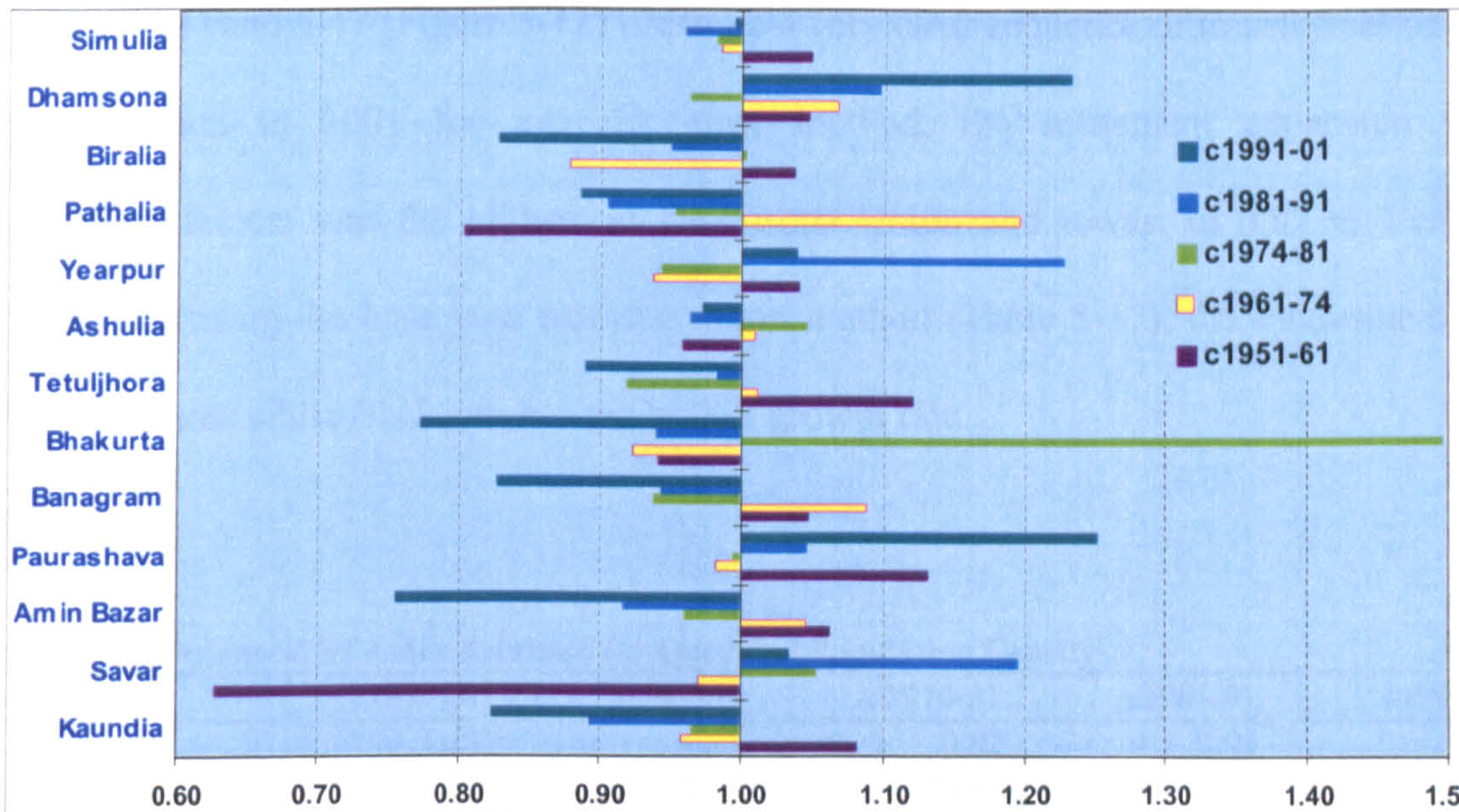
Union	c1951-61	c1961-74	c1974-81	c1981-91	c1991-01
Kaundia	**1.07**	0.96	0.99	0.89	0.80
Savar	0.57	**1.32**	**1.41**	**1.04**	**1.33**
Amin Bazar	**1.05**	**1.05**	0.99	0.92	0.74
Paurashava	**1.12**	0.96	0.90	**1.10**	**1.21**
Banagram	**1.04**	**1.09**	0.96	0.94	0.81
Bhakurta	0.93	0.93	**1.39**	**1.04**	0.75
Tetuljhora	**1.11**	**1.02**	0.94	0.98	0.87
Ashulia	0.95	**1.01**	**1.07**	0.96	0.95
Yearpur	**1.03**	0.94	0.97	**1.07**	**1.16**
Pathalia	0.82	**1.14**	0.92	0.91	0.94
Biralia	**1.03**	0.88	**1.03**	0.95	0.81
Dhamsona	**1.04**	**1.07**	0.99	**1.10**	**1.20**
Simulia	**1.04**	0.99	**1.01**	0.96	0.97

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Table 5-15: Base Year (1951) Transformation of Settlement Density (1951-2001)

Union	c1951-61	c1951-74	c1951-81	c1951-91	c1951-01	Rank 1951-01
Kaundia	1.07	1.03	1.03	0.92	0.74	11
Savar	0.57	0.75	1.06	1.09	**1.46**	**1.5**
Amin Bazar	1.05	1.11	1.09	1.00	0.74	11
Paurashava	1.12	1.07	0.96	1.06	**1.28**	**3**
Banagram	1.04	1.14	1.10	1.03	0.83	9
Bhakurta	0.93	0.87	1.20	1.25	0.94	7
Tetuljhora	1.11	1.13	1.07	1.05	0.91	8
Ashulia	0.95	0.96	1.03	1.00	0.95	6
Yearpur	1.03	0.97	0.94	1.01	**1.17**	**4**
Pathalia	0.82	0.93	0.86	0.79	0.74	11
Biralia	1.03	0.91	0.94	0.89	0.72	13
Dhamsona	1.04	1.12	1.10	1.21	**1.46**	**1.5**
Simulia	1.04	1.03	1.04	1.00	0.97	5

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002



Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Figure 5-9: Decennial ST index for the settlement expansion.

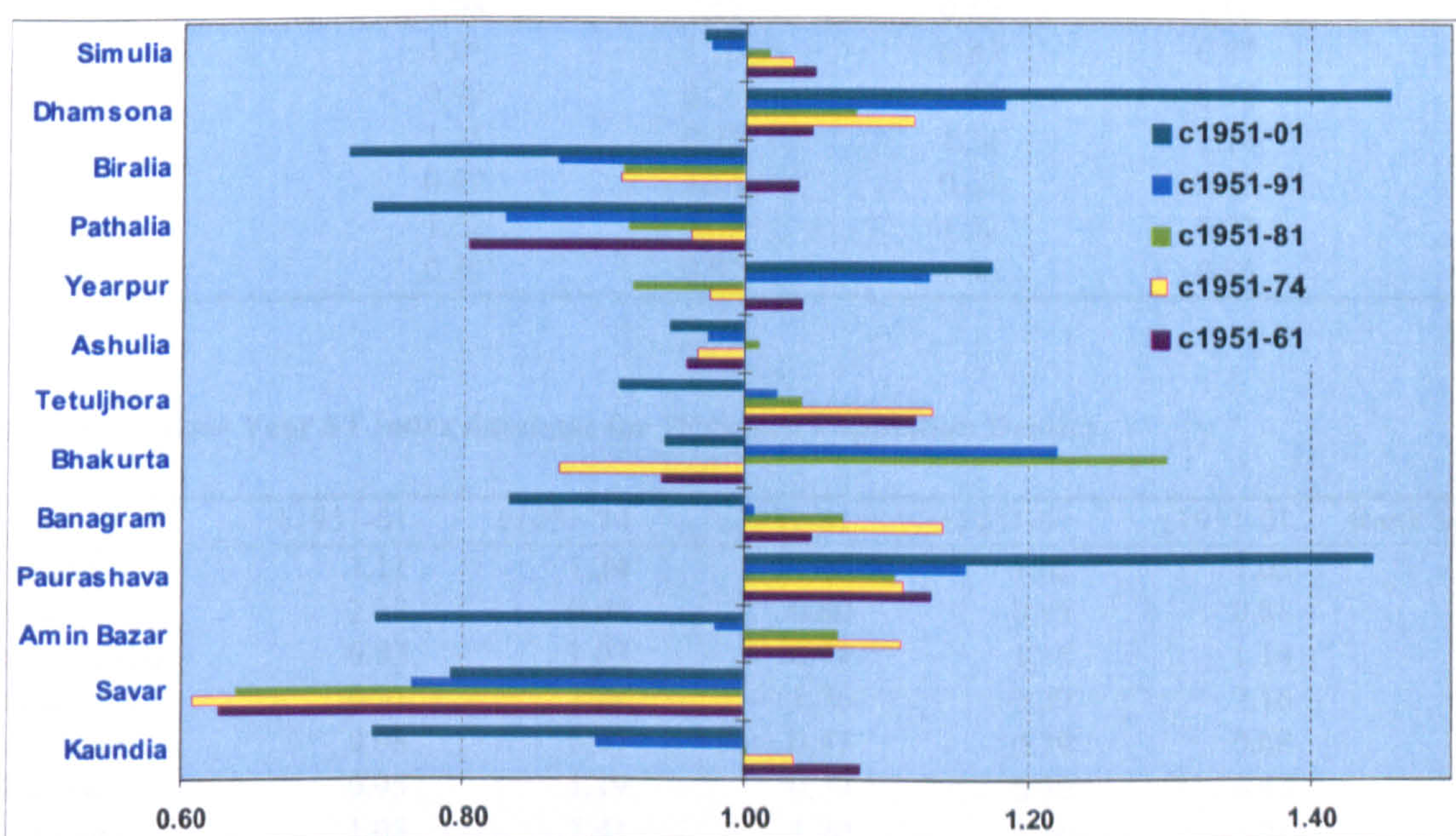


Figure 5-10: Base Year ST Index for settlement expansion

5.4.3. ST Index based on Occupied Population Density

How has the land occupied by the human population been increased over time? How was the land transformed on the flood free land during 1951-2001? The following Tables 5-16

(Figure 5-11) and 5-17 (Figure 5-12) illustrate a very clear sequence of transformations. In this approach in 2001 for inter-decennial method, the settlement expansion with population factors was the highest in Dhamsona Union and lowest in 0.82 in Yearpur Union. But using the base year transformation method (Table 5-17), the Paurashava has expanded most while Bhakurta has the lowest growth rate.

Table 5-16: Decennial ST Index database for Occupied Population Density

Union	c1951-61	c1961-74	c1974-81	c1981-91	c1991-01
Kaundia	1.11	1.21	0.82	0.93	1.01
Savar	2.12	0.02	20.22	1.19	0.93
Amin Bazar	0.83	1.24	0.77	1.46	0.99
Paurashava	0.91	1.36	1.42	1.35	0.91
Banagram	0.98	0.99	0.89	0.91	0.86
Bhakurta	0.95	1.26	0.50	0.84	0.88
Tetuljhora	1.08	1.31	0.85	0.96	1.04
Ashulia	1.01	1.10	0.83	0.87	1.25
Yearpur	0.93	0.25	3.93	0.75	0.82
Pathalia	1.35	0.95	1.34	1.14	1.08
Biralia	0.99	1.34	0.67	0.86	0.96
Dhamsona	1.02	0.60	1.53	0.93	1.40
Simulia	0.89	0.82	1.06	0.86	0.98

Table 5-17: Base Year ST Index database for Occupied Population Density

Union	c1951-61	c1951-74	c1951-81	c1951-91	c1951-01	Rank 51-01
Kaundia	1.11	1.34	1.10	1.02	1.03	6
Savar	2.12	0.04	0.80	0.95	0.88	8
Amin Bazaar	0.83	1.03	0.79	1.15	1.14	5
Paurashava	0.91	1.24	1.76	2.37	2.16	1
Banagram	0.98	0.97	0.87	0.79	0.68	10
Bhakurta	0.95	1.19	0.59	0.50	0.43	13
Tetuljhora	1.08	1.41	1.20	1.16	1.21	4
Ashulia	1.01	1.11	0.92	0.80	1.00	7
Yearpur	0.93	0.23	0.92	0.69	0.56	12
Pathalia	1.35	1.28	1.71	1.94	2.10	2
Biralia	0.99	1.33	0.88	0.77	0.73	9
Dhamsona	1.02	0.61	0.93	0.87	1.22	3
Simulia	0.89	0.73	0.77	0.66	0.65	11

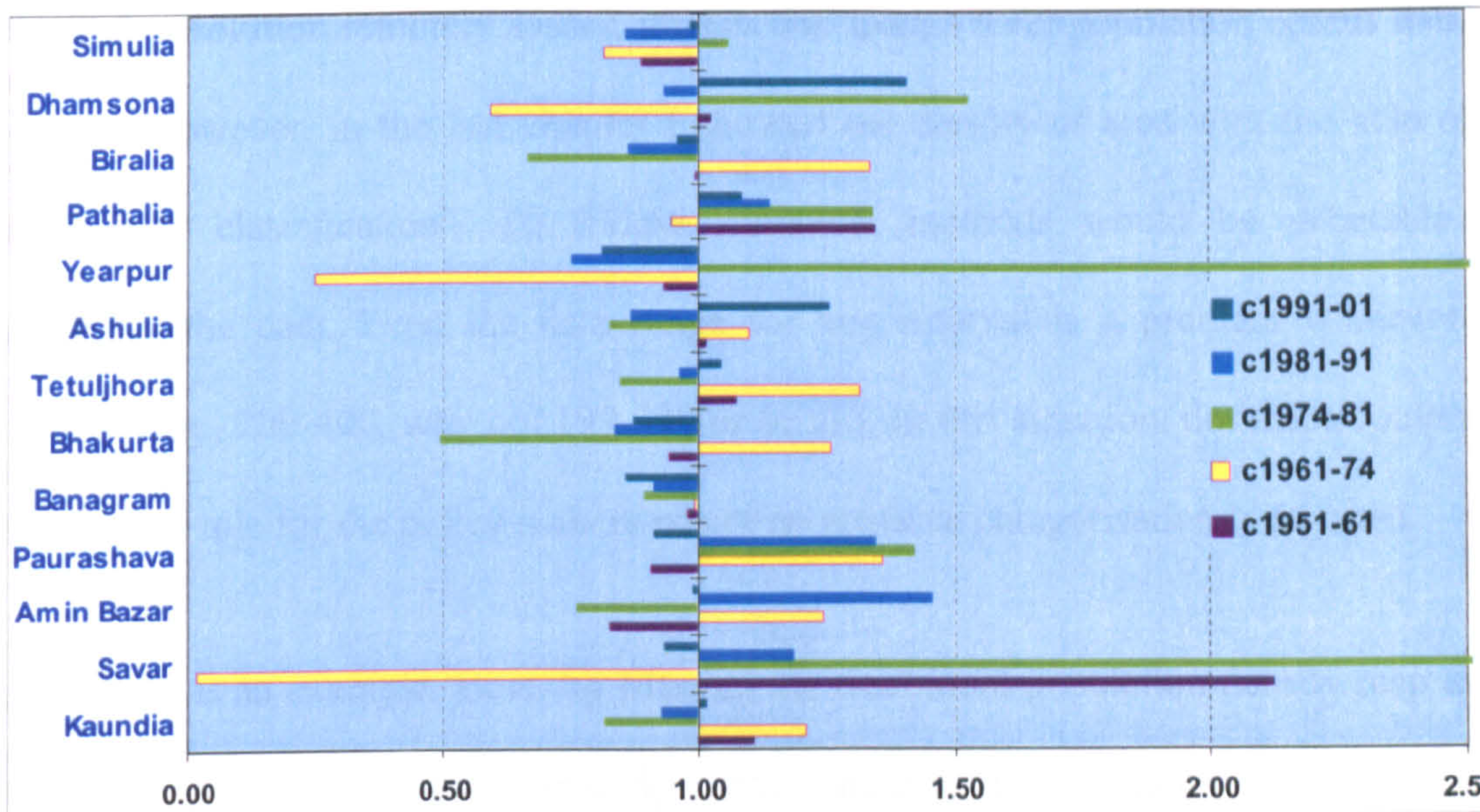


Figure 5-11: Decennial ST index comparisons for Occupied Population Density

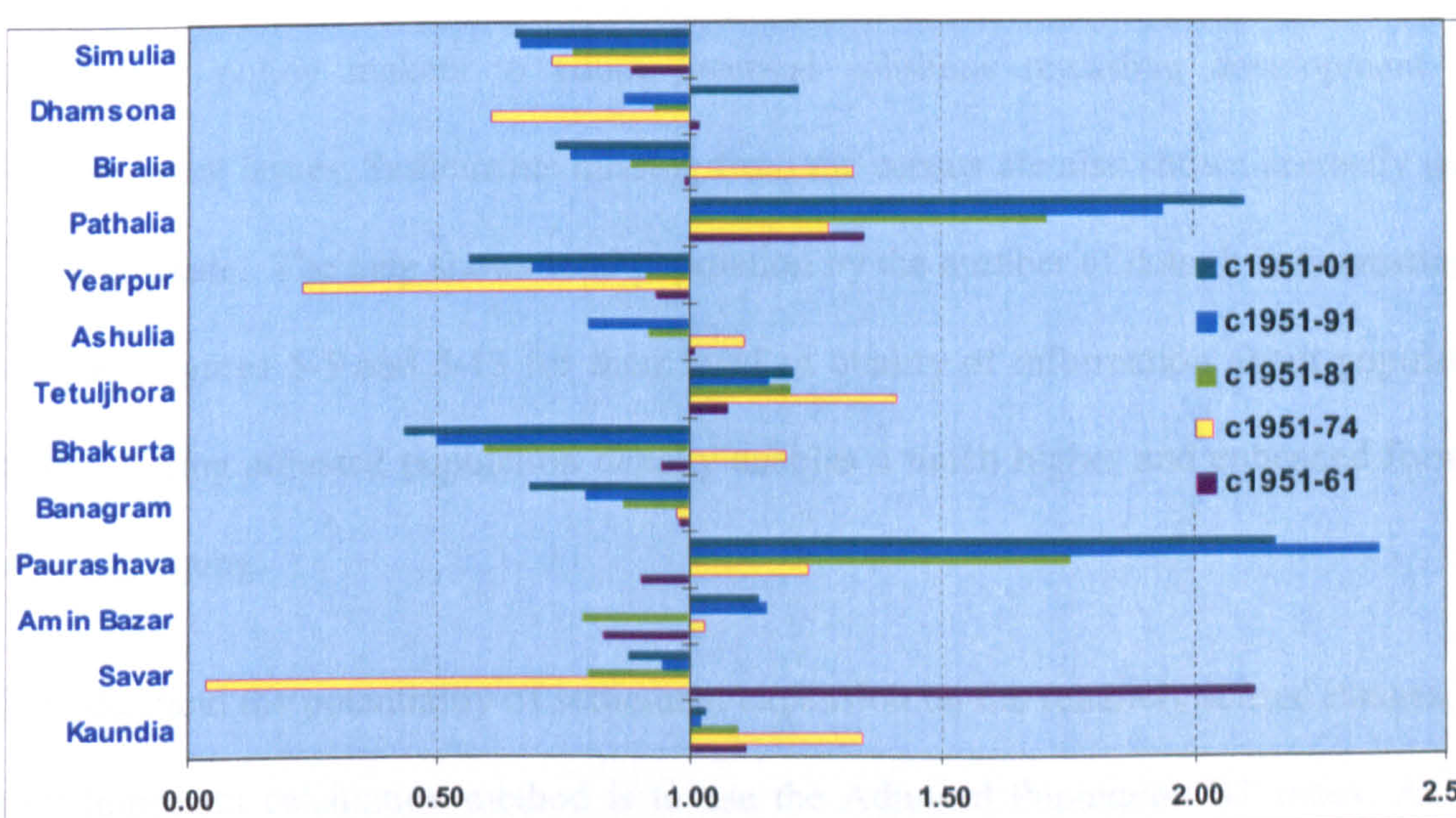


Figure 5-12: Base Year ST index comparisons for Occupied Population Density

5.4.4. ST Index based on Adjusted Population Density

Population density can be portrayed as a dot map (Figure 5-13). In the previous chapter, I discussed how the settlement area data can be merged with population data. To do this, both high-resolution remotely sensed images and mauza level population census data are required. However, in the last chapter I showed the density of area with the help of an 'equal area classification'. To follow statistical methods would be debatable for classifying the data. Even the data range for any interval is a problem whatever the outcome (e.g., 200-400, why not 199-399 or so on). In this situation, dot maps could play a significant role for the policy makers where no artificial categorisation is required.

Figure 5-13 is an example. Here, by filtering the traditional population density map using settlement locations based on remotely sensed images, 'interpretation techniques' have been used in order to enhance the quality of census data. Only inhabited areas are shown at sub-mauza (village and/or para) level with adjusted population density, which will help planners or policy makers to adopt practical solutions regarding development and environmental issues. Settlements missing from the census are also shown correctly using a special shade. The map shows total population by the number of dots. It is interesting to compare Figures 5-5 and 5-13 for their level of quality of information about population density. Using adjusted population density enables a much higher and enhanced form of census mapping.

To understand the potentiality of settlement expansion on the remotely sensed images, the most important calculation method is to use the Adjusted Population ST index. As this part of the chapter is important, I will explain all of the relevant information in detail to understand the background context and produce a very contrasting and meaningful picture of each union, so that the ultimate findings can be based on a good database foundation and can be used to find out why the Adjusted Population Density is much more important.

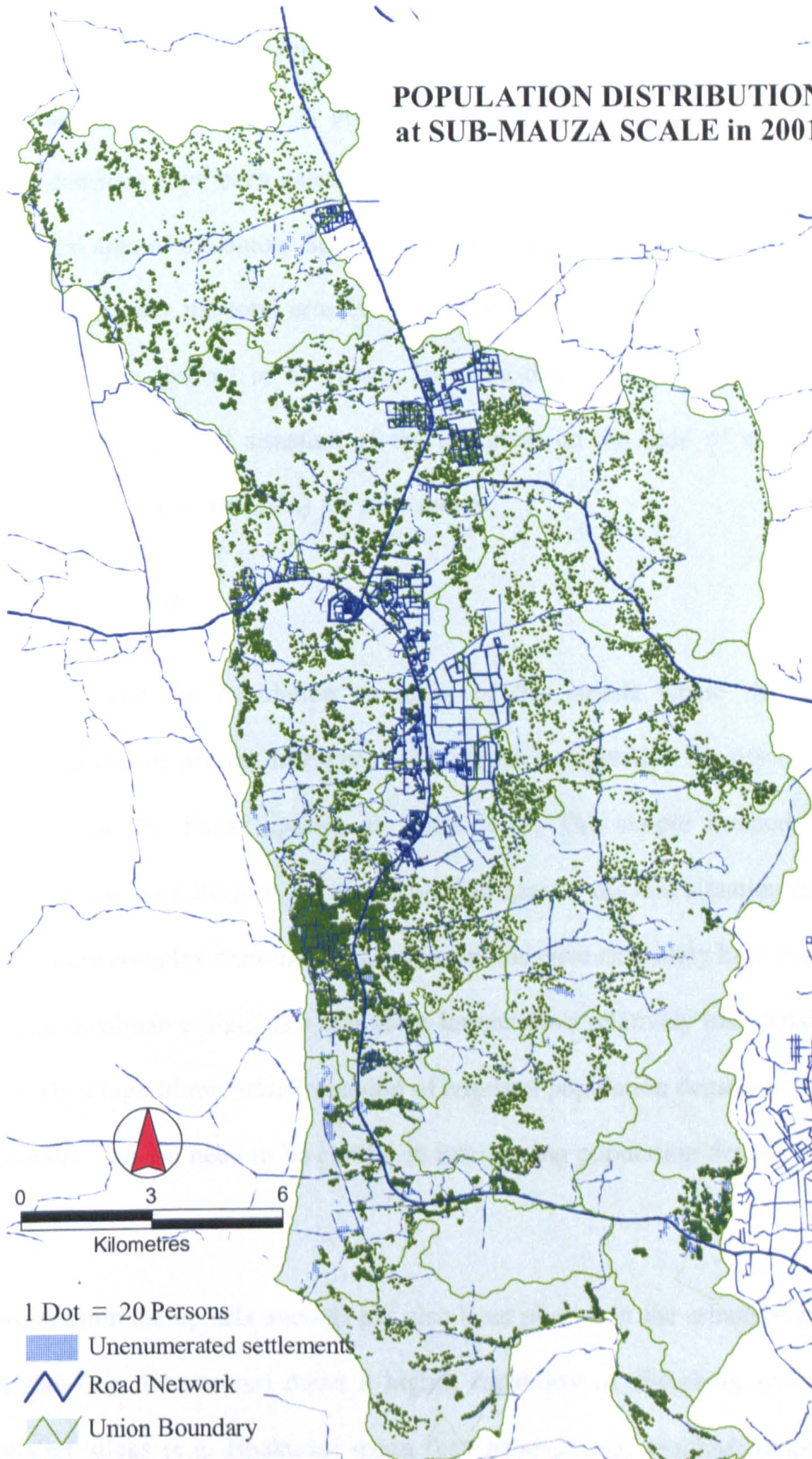


Figure 5-13: Based on Adjusted Population Density method, the distribution of population 2001of Savar upazila at sub-mauza level has been mapped. It is interesting to compare with Figure 4-12.

In this technique, the landmass suitable for settlement growth has been considered mainly based on their current as well as potential further expansion possibilities. The total population densities have been calculated based on the suitable landmasses in the union rather the total area of the union. So the chalas, kandis and dias have been digitised from satellite images. Later the total area has been measured using GIS methods. The total flood-prone area is ignored in this case. Then the density of population is calculated, which reflects the adjusted situation of the landmass on the light of current (23%) or potential land use (additional 28%) for settlements.

(a) Logarithmic Graph

Figure 5-4 showed the population strengths of the unions where the scale was a cumulative number of people. In Figure 5-14, adjusted population density is plotted on a logarithmic scale for Savar upazila at union level. The simple method of showing population density on a linear scale is not possible here as the real situation in the field is very much more complex than the ideal. Some unions have extremely high populations on their limited inhabitable highlands and some unions have relatively low densities. In this situation only a logarithmic transformation of adjusted population density gives a sensible representation. So we need to be careful in interpreting population densities represented as log values.

In the last column the upazila average has also been placed. In the urbanisation phase, the longer sticks (e.g. Dhamsona) mean a higher capability of absorbing more population while smaller sticks (e.g. Bhakurta) mean they have already reached almost saturation levels. The log scale for the Y-axis indicates a rapid change in decennial population density in the higher-placed bars. Kaundia and Amin bazaar unions contain an extreme high density similar to the nearby capital Dhaka while others will approach that level in decades to come. In cases of developing temporal segments, Paurashava accumulate very rapid changes for a long time between 1961 and 1991 and still the process continues while other unions had a relatively shorter take-off time for gaining development momentum. In the pre-development phase, the unions highly dependent on agricultural activities, and with a significant amount of floodplain land, attracted population. Chala land could not show a similar performance at that time because it was less attractive.

This logarithmic figure shows the following general aspects of the data:

- The Population growth rate is extremely high as the log-scale shows;
- The disparity of the sub-units (e.g. unions in an upazila) is considerable;
- Changes have been dramatic over time and were influenced by contrasting circumstances;
- The importance of visual understanding is required in a simple form to understand the complex contextual background;
- Shape variations in the development phases are known, for instance the pre-development, developing and urbanisation phases.;
- Sufficient data or supporting materials (like census and remote sensing) are available to explain the facts behind the data.

(b) Influence of Land Type

All of the above explanations are mainly influenced by the land types of the upazila and their proportions at upazila level. Land was the trigger for population growth in the agrarian society in the early decades as well as the developed society in the recent history for each of the individual administrative units. The Figure 5-15 shows the proportion of landmass on each union according to the land occupied by settlements in 2001, the flood free land left suitable for settlements expansion and the highly risky flood plain land located within union boundaries. Moreover, as an inset, a chart has been placed to show the proportion of the land categories of Savar upazila. This Figure shows that floodibility is the most influential factor in Bangladesh and much of the Indian subcontinent. Dhamsona and Ashulia have most of the flood-free landmass and also Simulia, Biralia, Pathalia, Yearpur and Savar have a significant ratio. The largest populated landmass is located in Paurashava union, which has almost reached saturation point. Kaundia, Amin Bazaar and Bhakurta have already reached saturation with no way to expand the settlement landmass horizontally for the last few decades. The reason for constant population increase in this area is due to vertical expansion through the construction of multi-storied buildings.

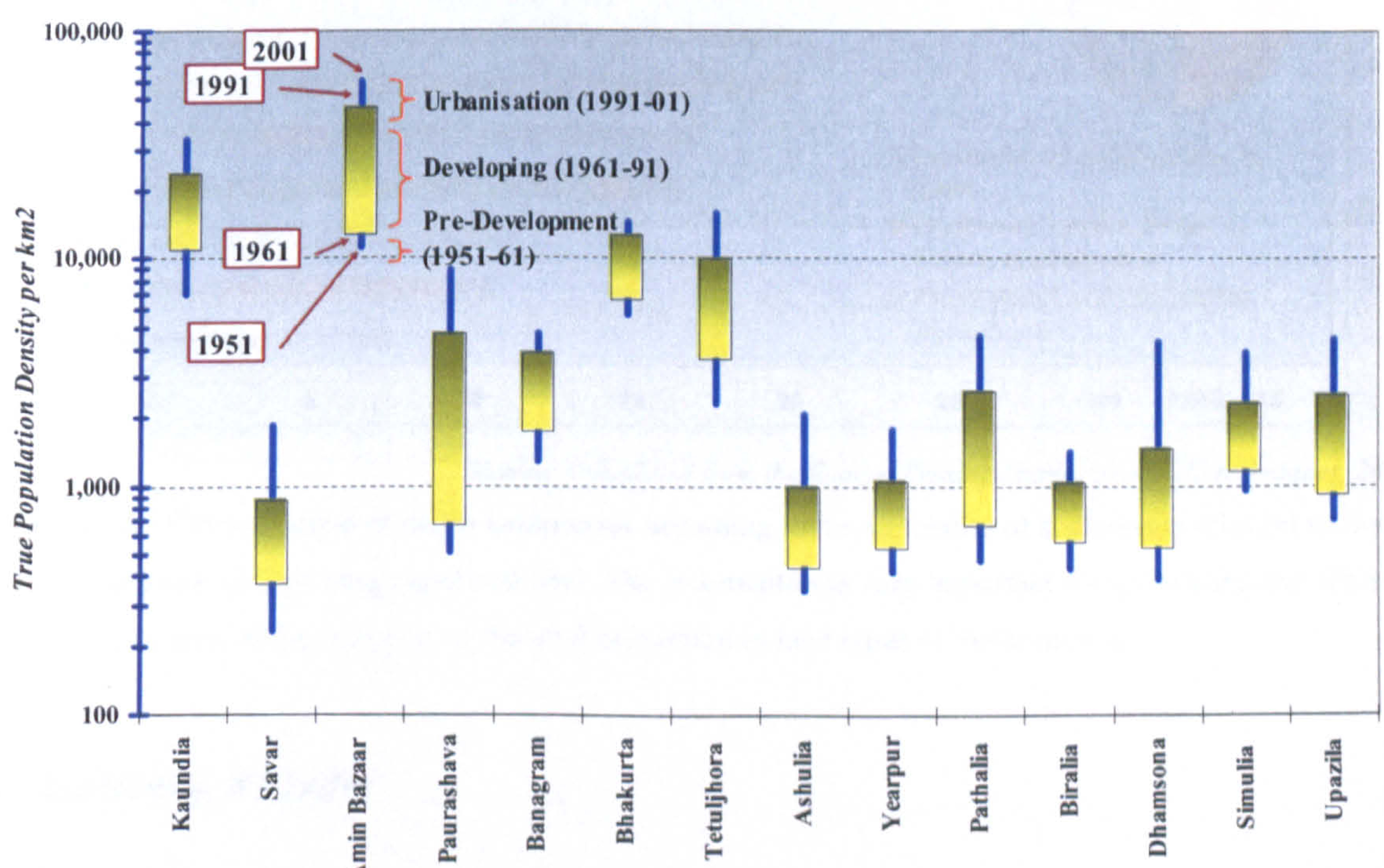
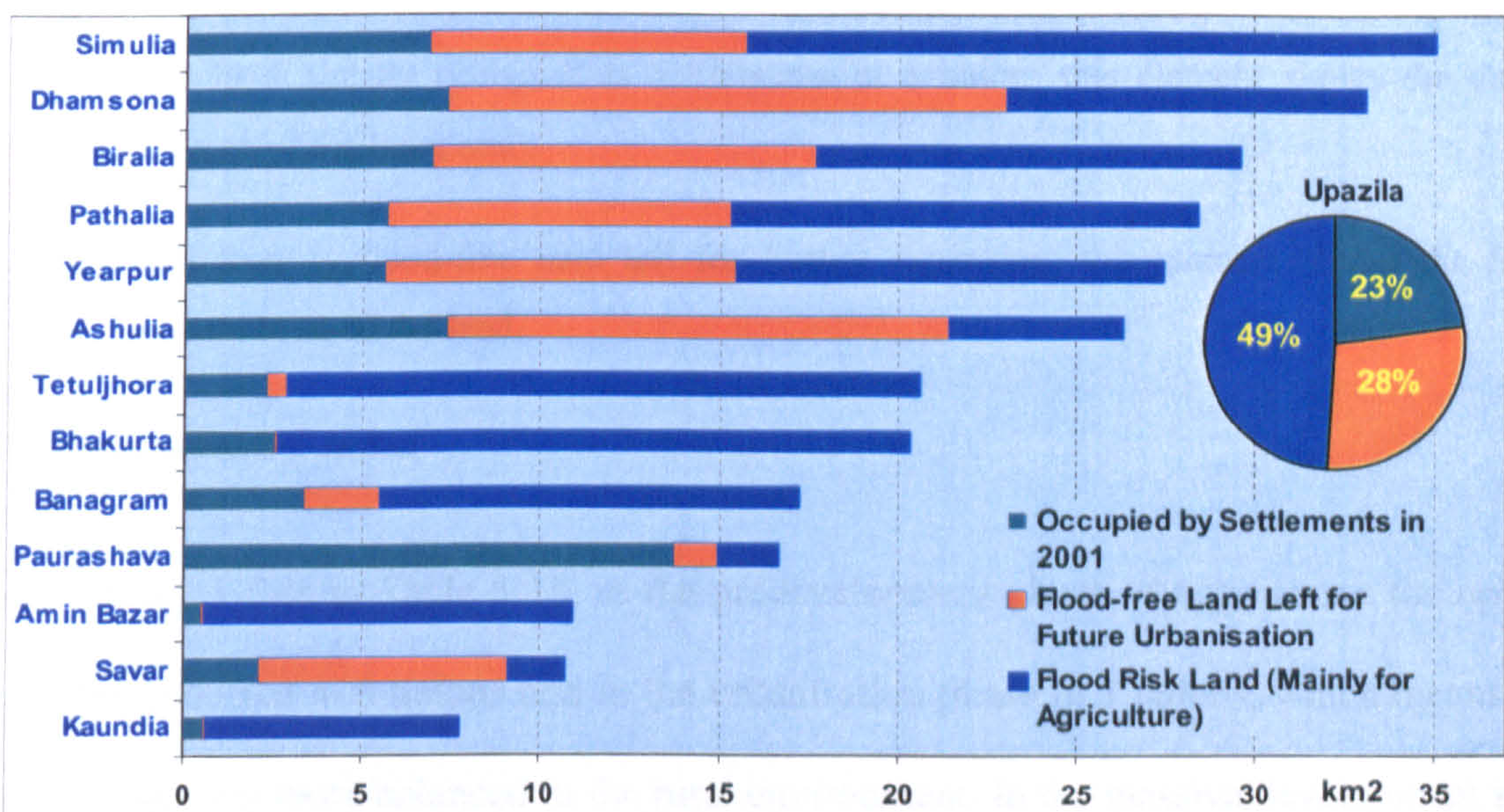


Figure 5-14: Adjusted population density at union level shows as a logarithmic scale the three stages of land transformations: Predevelopment, Developing and Pro-urban or urbanisation phases.

Due to a very limited land availability in Amin Bazaar and Kaundia unions for building new settlements, as shown in Figure 5-15, the load of population density is immense. These gigantic human loads are reflected in Figure 5-14 as their population bars belongs to the top level of the graph, with a logarithmic speed. In the urban environment, as observed in Dhaka, most of the ghettos, locally known as basti, have been initiated on past agricultural land on the *bydes*. Savar may face similar consequence in those unions with bydes or low lands. So from now, in my view this land should be protected by law and subject to detailed planning guidelines.



Source: Calculated from the Remote Sensing Images using GIS techniques, 2002.

Figure 5-15: The proportion of major landmasses according to the suitability of settlements relevant to flood-free, flood-prone and existing populated land. The informaiton is very important for calculating the adjusted population density. In the pie-chart, is the total proportion of land types of Savar upazila.

(c) Explaining ST Index

Now we can move toward an in-depth adjusted ST index analysis. The outcome of the land transformation is an increasing rate of in-migration in the upazila. For the in-migrants, we need sufficient land to hold the population capacities. In a floodplain country like Bangladesh, only flood-free land can give these opportunities, particularly where a potential transformation from a very rural society to an urban society is taking place. A long-term stability is highly expected as a significant amount of physical and economic resources will be invested. Mainly to avoid the destruction of these valuable assests, for example, a life-time's investment by people in housing, two major factors can be considered: one, avoid regular flooding of settlement areas; two, avoid river bank erosion or shifting. These two factors are only possible to implement in Savar upazila on certain land types, and that is flood plain chala land. These chala lands include:

1. The land already occupied as settlements in a union; this element shows the current strength of the land; and
2. Still there is flood-free land left for further expansion; this element shows the future potentialities of the land.

(d) Decennial ST Index

According to data in Table 5-18, in the predevelopment phase, change above the upazila average occurred in 8 unions and in the urbanisation phase in 5 unions, which means that the change was more balanced in the rural environment. In the massive development stage in the last decade the deviation from the mean was higher. It is calculated that the standard deviation during the intra-decennial 1951-61 was only 0.11 but this value rose more than double to 0.28 between 1991 and 2001.

The sequence of change happened (from rapid to average) in the pre-development change as **Savar (1.21) > Tetuljhora (1.20) > Kaundia (1.19) > Pathalia (1.10) > Banagram (1.017) > Paurashava (1.016)**. In contrast to that, in the pro-urban phase the situation changed dramatically and the transformation occurred as **Dhamsona (1.69) > Savar**

(1.24) > Ashulia (1.19) > Paurashava (1.10) > Pathalia (1.01). At the cost of Dhamsona and Ashulia, other 3 unions named Tetuljhora, Banagram and Kaundia have been wiped out from the race. No only that, the rate of change is also significant, for example Dhamsona joined in 2001 in the transformation race with a 1.69 score, while in 1961 Savar was in the highest position with only a 1.21 score. That means, in the mean time, that the disparity in the region also increased noticeably due to very uneven development initiatives in particular unions and high land distribution. As a result, the deviation has been remarkable and the above unions are getting most of the resources and investment opportunities. These analyses are based on last and first decades of the research scope.

In the developing phase, due to serious population data problems in Savar, Paurashava, Yearpur and Dhamsona, the entire result has been affected by 1974. This is reflected in the 1961-1974, 1974, 1981 data columns. The results were highly fluctuating here. With much more stable population census data during the 1981-1991 study period, the **Paurashava (1.48) > Amin Bazaar (1.34) > Savar (1.23) > Pathalia (1.04) > Dhamsona (1.01)** stands out as an area of high potential shown by a standard deviation 0.22. At the bottom of the union list, in the pre-development stage, came Amin Bazaar (0.87), in developing Phase (1981-1991) Yearpur (0.81), and in the urbanisation phase Bhakurta (0.66). In the bottom line, the nethermost point is also very deep at 0.6 instead of .08. There is no doubt, this shows negative impact of development elsewhere and the focus of the lowest transformation is also very unstable from Yearpur to Bhakurta.

To understand the database in detail, Table 5-18 is presented alongside Figure 5-16.

(e) Base Year ST Index

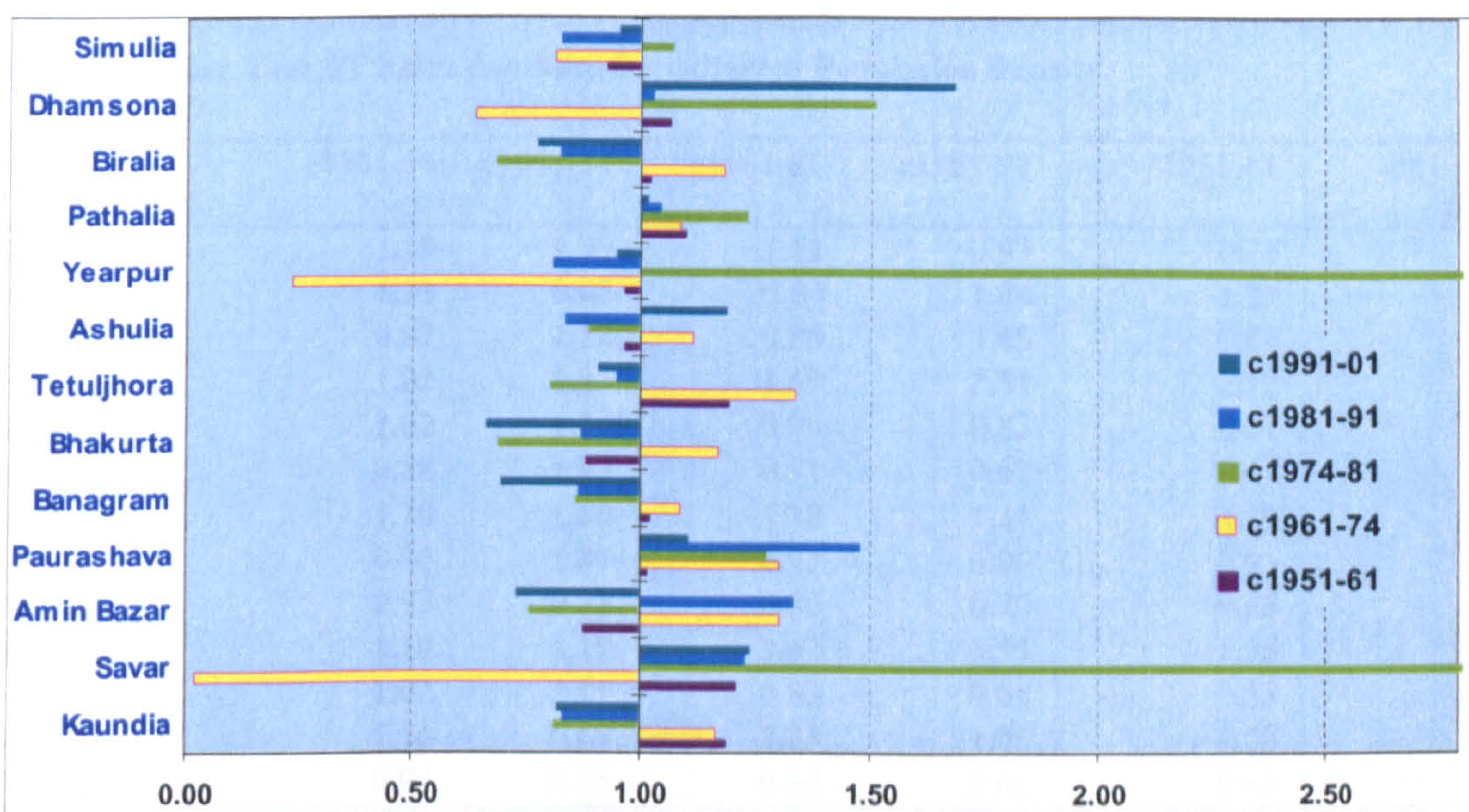
Use of the base year is a way of understanding the overall change. At all stages 1951 has been considered as a common year of analysis. The year 1951 is a reflection of a hundred years of pre-development evolution in this area, where all activities were mostly based on the primary economy. The interior chala land was occupied by forestry and only the lowlands were cultivated for boro agriculture. No *pucca* roads were to be found. Now the society has completely changed, as mentioned in the previous chapter, by so many land transformation factors and agents. So all changes can be indexed against the pre-development stage, i.e. with 1951. So the categories are here: 1951-1961, 1951-1974, 1951-1981, 1951-1991 and 1951-2001.

Table 5-18: Decennial ST index database for Adjusted Population Density

Development Phases	Pre-developed Phase	Developing Phase			Urbanisation Phase
Decades	**c1951-61**	**c1961-74**	**c1974-81**	**c1981-91**	**c1991-01**
Kaundia	**1.19**	**1.17**	0.81	0.83	0.82
Savar	**1.21**	0.02	**28.42**	**1.23**	**1.24**
Amin Bazaar	0.87	**1.31**	0.75	**1.34**	0.73
Paurashava	**1.02**	**1.31**	**1.28**	**1.48**	**1.10**
Banagram	**1.02**	**1.09**	0.86	0.86	0.69
Bhakurta	0.88	**1.17**	0.69	0.87	0.66
Tetuljhora	**1.20**	**1.34**	0.80	0.95	0.91
Ashulia	0.96	**1.11**	0.89	0.84	**1.19**
Yearpur	0.97	0.24	**3.80**	0.81	0.95
Pathalia	**1.10**	**1.08**	**1.23**	**1.04**	**1.01**
Biralia	**1.02**	**1.18**	0.69	0.82	0.78
Dhamsona	**1.06**	0.64	**1.51**	**1.02**	**1.69**
Simulia	0.92	0.81	**1.07**	0.82	0.95

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

As shown in Table 5-19 (or Figure 5-17), the first decennial values are **Savar (1.21) > Tetuljhora (1.20) > Kaundia (1.19) > Pathalia (1.10) > Banagram (1.017) > Paurashava (1.016)**, similar to Table 5-18. But in later years these have been changes which with need to be explained. The final comparison column of 1951-2001 gives an overall glimpse of change during the entire study period of fifty years. Here, the higher ranking unions above the average (1.00) are **Paurashava (2.77) > Dhamsona (1.78) > Pathalia (1.55) > Savar (1.28) > Tetuljhora (1.10).** This statement demonstrates the enormous transformation in the half century. Comparisons using the decennial ST Index give **'phase wise'** change while this base year ST index shows **'overall'** change of the upazila. Both of them are important depending on the objectives. The *paurashava* was in the last of the above average group in 1961 but recently in 2001 it has taken the lead in comparison to 1951. The paurashava invested effort in every decade since the beginning with resulting cumulative success.



Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Figure 5-16: Decennial ST index comparisons for Adjusted Population Density. Due to data problem in 1974, some unions show a very unrealistic figure.

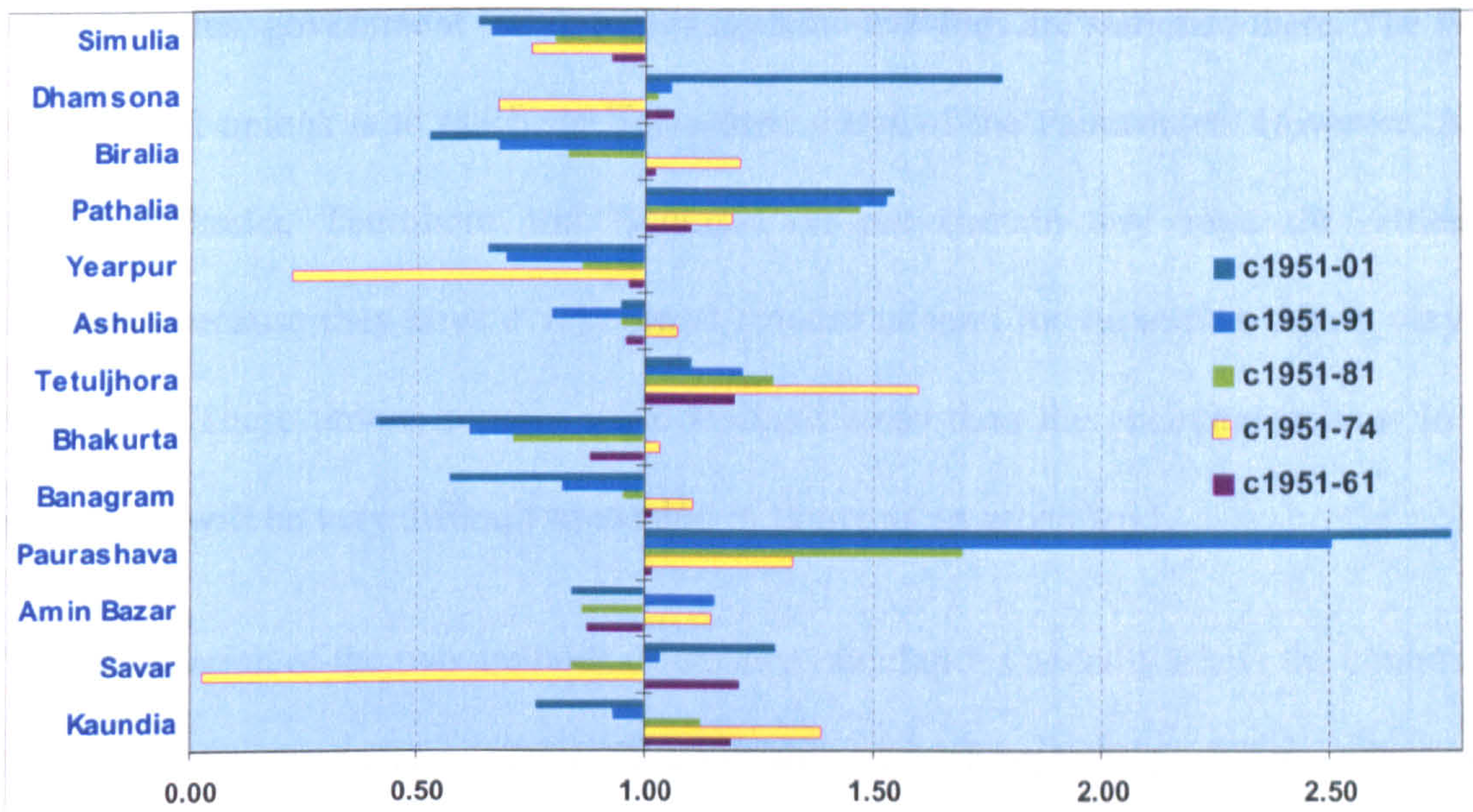
If we ignore the 1974 Standard Deviation (0.45) of the upazila at union level due to its poor data quality, the result is very conclusive. The gap is widening more and more. In the 1951-61 period, the standard deviation was 0.11, 1951-81 it was 0.29, in 1951-91 0.51 and in 1951-01 0.66. In the early years of the study, the entire area was like a big village, so there was a very little scope for inequality in the region. The subsequent gap was due to some areas continuing to be rural in nature while others are now very advanced, with modern urban facilities and infrastructural benefits. The economic situation is completely contrasting between the primary and secondary (with some tertiary) economic sectors. For example, the Export Processing Zone is in Dhamsona Union and there is no structure in Biralia Union. Additionally Paurashava is getting massive benefits for its role as a mini form of CBD (central business district) for the entire upazila. These sorts of factors are responsible for the higher deviation in the study area and demonstrate the utility of the base year ST Index approach.

Table 5-19: Base Year ST Index database for Adjusted Population Density

Union	c1951-61	c1951-74	c1951-81	c1951-91	c1951-01	1951-2001 Rank
Kaundia	**1.19**	**1.39**	**1.12**	0.93	0.76	8
Savar	**1.21**	0.03	0.84	**1.04**	**1.28**	4
Amin Bazar	0.87	**1.14**	0.86	**1.15**	0.84	7
Paurashava	**1.02**	**1.33**	**1.69**	**2.51**	**2.77**	1
Banagram	**1.02**	**1.11**	0.95	0.82	0.57	11
Bhakurta	0.88	**1.03**	0.71	0.62	0.41	13
Tetuljhora	**1.20**	**1.60**	**1.28**	**1.21**	**1.10**	5
Ashulia	0.96	**1.07**	0.95	0.80	0.95	6
Yearpur	0.97	0.23	0.86	0.70	0.66	9
Pathalia	**1.10**	**1.19**	**1.47**	**1.53**	**1.55**	3
Biralia	**1.02**	**1.21**	0.83	0.68	0.53	12
Dhamsona	**1.06**	0.68	**1.03**	**1.05**	**1.78**	2
Simulia	0.92	0.75	0.80	0.66	0.63	10

Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

This method can also be applied for agricultural census data and the issues relevant to development and planning. In the following section, some fascinating results can be found if we use different methods for a common purpose.



Source: Calculated from Population Census Reports of Bangladesh and GIS-RS data, 2002

Figure 5-17: Base Year ST index comparisons for Adjusted Population Density

5.5.0. Summarising Outcomes

(a) Combining Density Methods

In Figure 5-18, the two-way scatter plot shows a unique example of a combination of traditional density and adjusted density of population per km^2 in a two-way scatter graph that gives a glimpse of realistic field situation in Savar upazila. Here both census and remotely sensed data contributed to calculating the results. Unions shown within the elliptical boundary are the zones with most potential in terms of the availability of flood-free land in the upazila for the expansion of urban growth. These are from the lower left: Biralia, Yearpur, Savar, Ashulia, Simulia, Banagram Pathalia and Dhamsona unions.

In the semi-circle, the leftward unions are progressing slowly in comparison to rightward unions. The Paurashava possesses an ideal pro-urban situation like a mini-CBD where sufficient high lands are available for a very standard population density and most of the service centres, government HQs and commercial activities are stationed there. The target of lower left unions is to reach the equivalent status of the Paurashava. However, Amin Bazaar, Kaundia, Tetuljhora and Bhakurta do not contain any hope for settlement expansion because they have a very small amount of land for expansion with a very big population. These unions contain more lowland areas than the encircled unions. In this situation, it will be very difficult to expand in future as an urban land.

The combination of the two methods of density calculations actually filters the contrasting and distinctive unions very easily. Through this way of separation, the most important phenomena are sieved based on the following logic where the x-axis represents the traditional population density and the y-axis represents adjusted population density in the land types like Savar upazila, where every metre of inundation level is very crucial for any land-use activity. Here three type of cluster can be seen:

1. Homogeneous and balanced population change like the paurashava;
2. Massive population concentration on a limited land like Amin Bazaar; and
3. Lower population densities with higher potentials like Dhamsona.

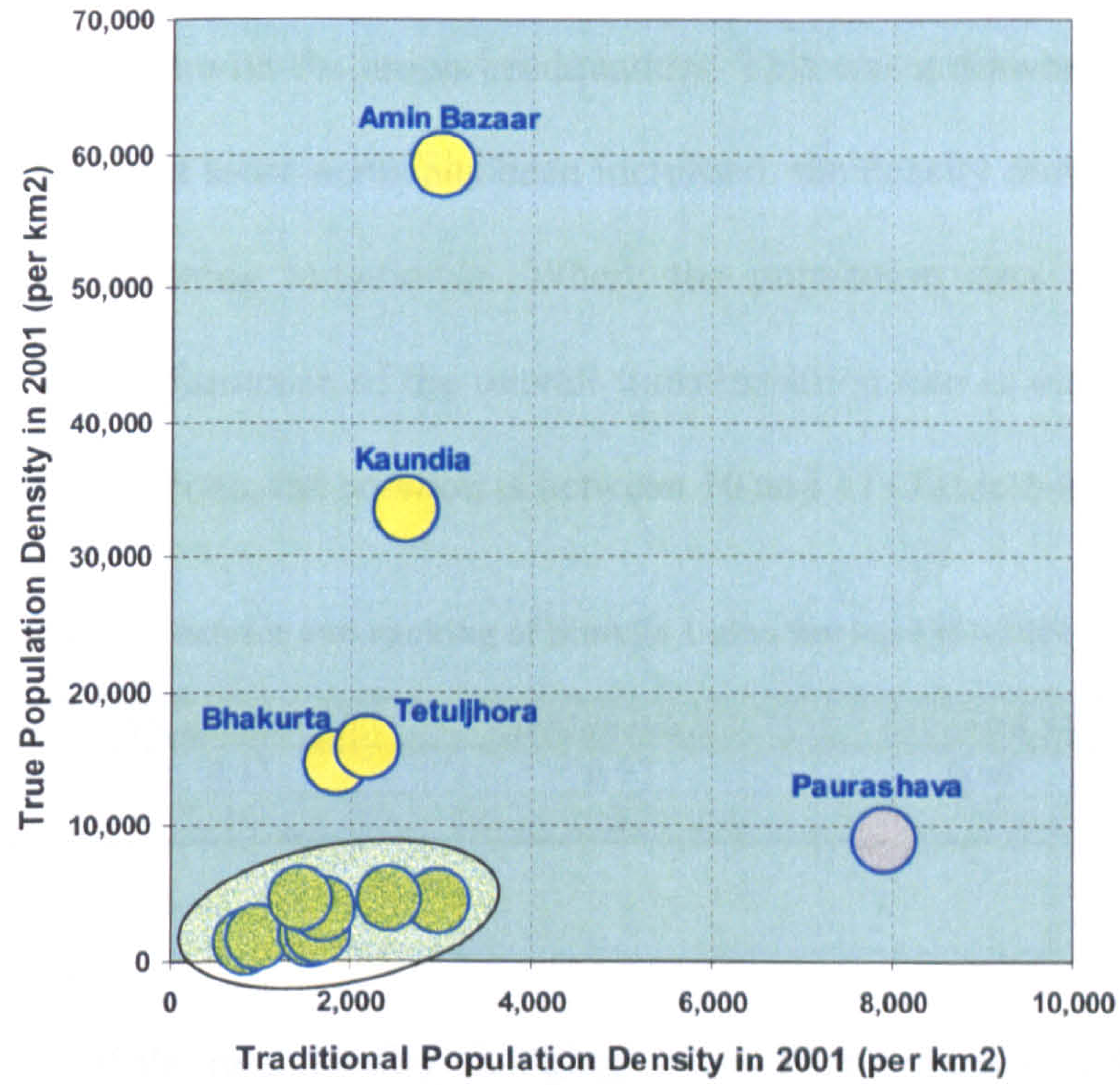


Figure 5-18: In this two-way scatter plot, the X-coordinate represents traditional population density while Y-coordinate shows adjusted (true) population density of all unions of Savar upazila of 2001.

(b) Ranking the Land Transformation (Base Year 1951)

Based on the above ST indexes, we can sum up the following findings. In the following Tables (6.20 to 5-32) a list of different methods of spatio-temporal analytical results is presented for comparison. Also, there are 13 sub-regions of Savar upazila. The top-ranking union has been indicated as 1 while the lowest ranking is shown as 13. The basis of this comparison is an understanding that the different results are based on using different parameters. For the all results, the base year for the union is 1951 and the latest year was 2001.

<u>**Simulia Union:**</u>

Though Simulia is the largest union in the upazila, it has failed to secure its position due to its highly dependency on only agricultural activities. So the density of population and settlements did not increase proportionately. Moreover, until 1999, there was no direct (*pucca*) road connexion with the union headquarters. This was a drawback for the union. Though the total area of settlements has been increased, the density remained low. So far it does not show anything remarkable. Where the population data is linked (except settlement ST), the performance of the overall transformation rate is very low. Out of 13 local administrative regions, the position is between 10 and 11 (Table 5-20).

Table 5-20: Simplified ST indexes and ranking of Simulia Union during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	0.63	0.97	0.65	0.63
ST Rank (1-13)	10	5	11	10

Dhamsona Union:

Dhamsona is one of the most swiftly changing unions in the upazila, particularly in the last decade due to the establishment of the EPZ in the area. Moreover, a very good link with the capital city was also constructed at the same time. A massive number of people have migrated in to this area to find jobs in and around EPZ. The rate of change is much more than the average (>1), so the indicator has reached 1.78 (Table 5-21). The rank of the union has been on the basis of sorts of indicators within the top 1-3 ranking unions.

Table 5-21: Simplified ST indexes and ranking of Dhamsona Union during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	1.78	1.46	1.22	1.78
Rank (1-13)	2	1.5	3	2

Biralia Union:

The result in Table 5-22, shows that this is one of the most backward unions in Savar upazila. Though the union has a significant amount of highland, the other economic and structural phenomena are not available in the area. So the area can be considered as a neglected part of Savar. So far, there are no significant pucca roads in this area. In the wet season, small boats are the most effective transport system.

Table 5-22: Simplified ST indexes and ranking of Biralia Union during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	0.53	0.72	0.73	0.53
Rank (1-13)	12	13	9	12

Pathalia Union:

Pathalia union shows (Table 5-23) impressive results during the 1951-2001 period. This basically happened due to the construction of the university in the eastern part of the union along with other government establishments. Jahangirnagar University has had a significant role in this area. Though the total settlements have not expanded significantly in terms of km^2, because some villages were destroyed by the land acquisition policy in the early 1960s, the population growth rate has nevertheless accelerated due to government policy. So its rank is in the top 3 where population parameters are considered.

Table 5-23: Simplified ST index of Simulia Union of Pathalia Union during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	1.55	0.74	2.10	1.55
Rank (1-13)	3	11	2	3

Yearpur Union:

There is no doubt that this area has received least attention, but in the next decade it will probably draw the limelight as happened to Dhamsona union. This is because this union will play a role at the end a new bridge between the EPZ and Dhaka capital due to the recent construction of a road in the early 2000s. So there are lots of chances to develop the area very soon. However, the area is still belongs to the bottom ranking unions though the physical expansion of settlements has risen dramatically reflected in the Settlement ST as 4 (Table 5-24).

Table 5-24: **Simplified ST indexes and ranking of Yearpur Union during 1951-2001**

ST Index:	*Traditional ST*	*Settlement ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	0.66	1.17	0.56	0.66
Rank (1-13)	9	4	12	9

Ashulia Union:

Ashulia in general plays a moderate role in land transformation. It is almost parallel to the upazila's process of land transformation over the last 50 years (Table 5-25). The changes are very close to 1, which indicates an average change. The reason is, because the location of the area is exceptionally well placed and now it is connected by the road network. Over the last decades, the changes were dependent on agricultural resources, but it will be a part of a massive settlement expansion very soon.

Table 5-25: **Simplified ST indexes and ranking of Ashulia Union during 1951-2001**

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	0.95	0.95	1.00	0.95
Rank (1-13)	6	6	7	6

Tetuljhora Union:

All results here reflect the average development scenario (Table 5-26). Though there are no *chala* lands in this union and it is mainly dependent on *kandis,* the location is unique. The two major national highways meet here and recently through the construction of the Singair Bridge, the area has come under the spot light of development. Therefore the potential of land is very high but there are no more flood-free lands on which to expand. So, near the roads of this union, the lowland has been filled up by earth and expansion has been taking place like strips or ribbons. A number of industrial units have been established over the last 15 years.

Table 5-26: Simplified ST indexes and ranking of Tetuljhora Union during 1951-2001

ST Index:	*Traditional ST*	*Settlement ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	1.10	0.91	1.21	1.10
Rank (1-13)	5	8	4	5

Bhakurta Union:

This is one of the poorest unions in the upazila, as reflected in the statistics (6.27). Due to massive river bank shifting in the 1950s and 1960s a significant amount of local resources went under water. However, new settlement clusters have been built on kandis in recent decades, so the total area has been increased again. The settlements are surrounded by vast chars, which are suitable for agriculture practices. There is no chance of heavy infrastructural developments in this union, because it is very low lying and there is always the risk of the river bank shifting and of prolonged deep flooding. The settlement areas here are already saturated and there is a very minimal chance of attracting more people.

Table 5-27: Simplified ST indexes and ranking of Bhakurta Union during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	0.41	0.94	0.43	0.41
Rank (1-13)	13	7	13	13

Banagram Union:

This, the only union surrounded by other unions within Savar upazila, is not in good shape for development. Most of the results show that it belongs to one of the bottom ranking unions. The union is surrounded by bydes with no direct link to a pucca road. That is why the area is mostly neglected and it has been deprived of development activities. The ranks shown in Table 5-28 between 9 and 11 are not promising for land transformation though a small amount of land is available for further expansion of settlements only.

Table 5-28: Simplified ST indexes and ranking of Banagram Union during 1951-2001

ST Index:	*Traditional ST*	*Settlement ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	1.02	0.83	0.68	0.57
Rank (1-13)	11	9	10	11

Savar Paurashava:

This is the most impressive part of the upazila and it has been enriched with many development and land transformation factors. Currently, this is the only municipal area in the study zone. Since 1951, progress in this area has been dramatic due to the construction of the National Highway connecting the headquarters of the upazila. A lot of educational, business and commercial centres have flourished on the basis of good communications with the capital Dhaka, 30-40 minutes away by bus.

The early total dependency on waterways has become a road dependency. The highlands here was not so attractive as people were highly reliant on 'surface-water' systems (e.g. rivers, bydes and pukurs) for their everyday usage. Because the interior highlands were extremely dry in the winter and early summer time, the lack of water was a problem here, so people lived in the periphery areas close to the surface water. But now everything is dependent on ground water (tube wells, deep tube wells and tap water) systems. So the highlands are much more attractive due to their flood-free nature.

The creation of the *paurashava* (municipality) by splitting Savar union in the mid-1990s gave it great prominence then ever. This is reflected in all of the spatio-temporal indexes. Now, the area is the top-ranking part of the *upazila* (Table 5-29).

Table 5-29: Simplified ST indexes and ranking of Savar Paurashava during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	2.77	1.28	2.16	2.77
Rank(1-13)	1	3	1	1

Amin Bazaar Union:

This most promising location has very limited flood-free land is the dilemma of the union. Despite the highest density of population since the predevelopment phase, the rate of transformation is very low here, as a consequence of reaching saturation point and, as a result, the overall rank is below that expected of this union, that is 7 as illustrated in Table 5-30.

Table 5-30: Simplified ST indexes and ranking of Amin Bazaar Union during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	0.84	0.94	1.14	0.84
Rank(1-13)	7	11	5	7

Savar Union:

Savar Union is a now mostly (north-east block) covered by government institutions. The progress made in this area has been rapid as shown in its rank. Though the performance in occupied settlements is very poor, other parameters are excellent and less than 5 (Table 5-31).

Table 5-31: Simplified ST indexes and ranking of Savar Union during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	1.28	1.46	0.88	1.28
Rank(1-13)	4	1.5	11	4

Kaundia Union:

Kaundia is similar to Amin Bazaar, with similar land types. The national highway touches Amin Bazaar but Kaundia does not have this advantage. So due to the impact of the highway, the position of Kaundia is slightly worse than Amin Bazaar and its overall position is close to 8 (Table 5-32).

Table 5-32: Simplified ST indexes and ranking of Kaundia Union during 1951-2001

ST Index:	*Traditional ST*	*Settlements ST*	*Occupied ST*	*Adjusted ST*
1951-2001:	0.76	0.74	1.03	0.76
Rank(1-13)	8	11	6	8

(c) Mapping Spatio-temporal Change

From the above ST index analysis we can understand the level of change in numeric values. Also, it helps us to understand a relative comparison amongst the unions and we can also project it for future land transformation. But the numeric values cannot illustrate the level of change in the field and the actual distribution of settlement and the relative change with respect to particular year. For example, as shown in the Table 5-21, the ST index for settlement density has been increased to 1.46 for Dhamsona Union. But how does it look on the map? GIS have the power to demonstrate the change. For the planner and the decision maker, to find out this answer is very important, particularly the locational factors and land features that are important in this sort of study. If we look at the map (Figure 5-19) and see Dhamsona union carefully, it should be easy to understand the massive expansion of settlements over the last half century. It will help to find out in which part of the union the major settlement expansion occurred; especially if this map is overlapped with the population density map. Moreover, the emerging road network and land types can also explain the reason for suitability of settlement growth and pattern. For detailed analysis, the ST index gives clues where we can carry our further study on the particular sites. Some factors may be overlooked in the ST index, say for instance, in Dhamsona union, some villages have been completely deserted during the 'developing phase' due to government land acquisition and implementation policy. This information could not be accommodated in the ST method. In this case, only mapping the data can give the real picture of the union. So the employment of GIS approaches, the interpretation of ST is possible.

In the case of Dhamsona, it can be seen that the western part of the union has expanded dramatically as there were no settlements in here 1951. On the remote sensing images, the river was clearly flowing in this area in 1951 and has now shifted further west of the upazila boundary.

The Paurashava area is burgeoning around the national highways and expanding rapidly. Small clusters of settlements adjoin each other after 50 years of transformation. This is now the biggest settlement conglomeration in the upazila. Remote sensing has a special role to understand this sort of phenomenon from space at an acceptable interval of time while census data can provide its population dynamics. This high resolution imagery-based map can contribute to the efforts of environmental activists, policy monitoring and implementation agencies, or even local primary school mapping.

In this chapter I have focused on settlement due to its direct link with the census database. But other features can also be liked together to carry out similar sort of study.

(d) Progression of Settlements Transformations

Historical runs of data at decennial interval or single year Population figures mentioned in census reports do not give any visual shape and process of change over time. The land they occupied is not mentioned. As a result it is very difficult to understand the local physical features and phenomena properly. Particularly, land types and development centres are responsible for most of the alteration on land, which has triggered settlement pattern behaviour. In this case remote sensing data can play a very positive role in order to understand the local heterogeneity and micro-complexity. More realistically, only a sequence of images of the same area for long time can give an expected result and help to understand the gradual change of any settlements at a decennial rate. But the condition is that the images be available during the times of major change.

Savar is a unique example of this kind of research as in 1951 it remainded in the era of a complete rural society with no pucca road network and no development activities or visible infrastructures. The only landmark of Savar at that time was the 7th or 8th century clay ford and a few scattered archaeological sites with large pukurs. This picture reflected hundreds of years of gradual humanisation. Both the predevelopment and development phases are marked with significant footprints on the images. Here census data gives back to the remote sensing images. Using GIS overlap techniques and spatial analyst modules for remote sensing data, coupled with ground verification, some interesting settlement transformations have been exposed.

The following evidence has emerged from the remote sensing data about how the land mass has changed over time in the study area. The remote sensing images of the last five decades are the most impartial witness of the land transformations. The evidence was checked during the fieldwork by observation, interviewing and DGPS techniques.

Settlement Transformed in several ways as seen during photo interpretations:

(1) **Settlement Expansion:** After saturation of a settlement area by its own population capacity, over population was responsible for further expansion. Due to the pressure of population on the land, the settlement areas have expanded to the outskirts. On Chala land it is basically from margins to interior. But on Tek, the expansion occurred from interior to margins.

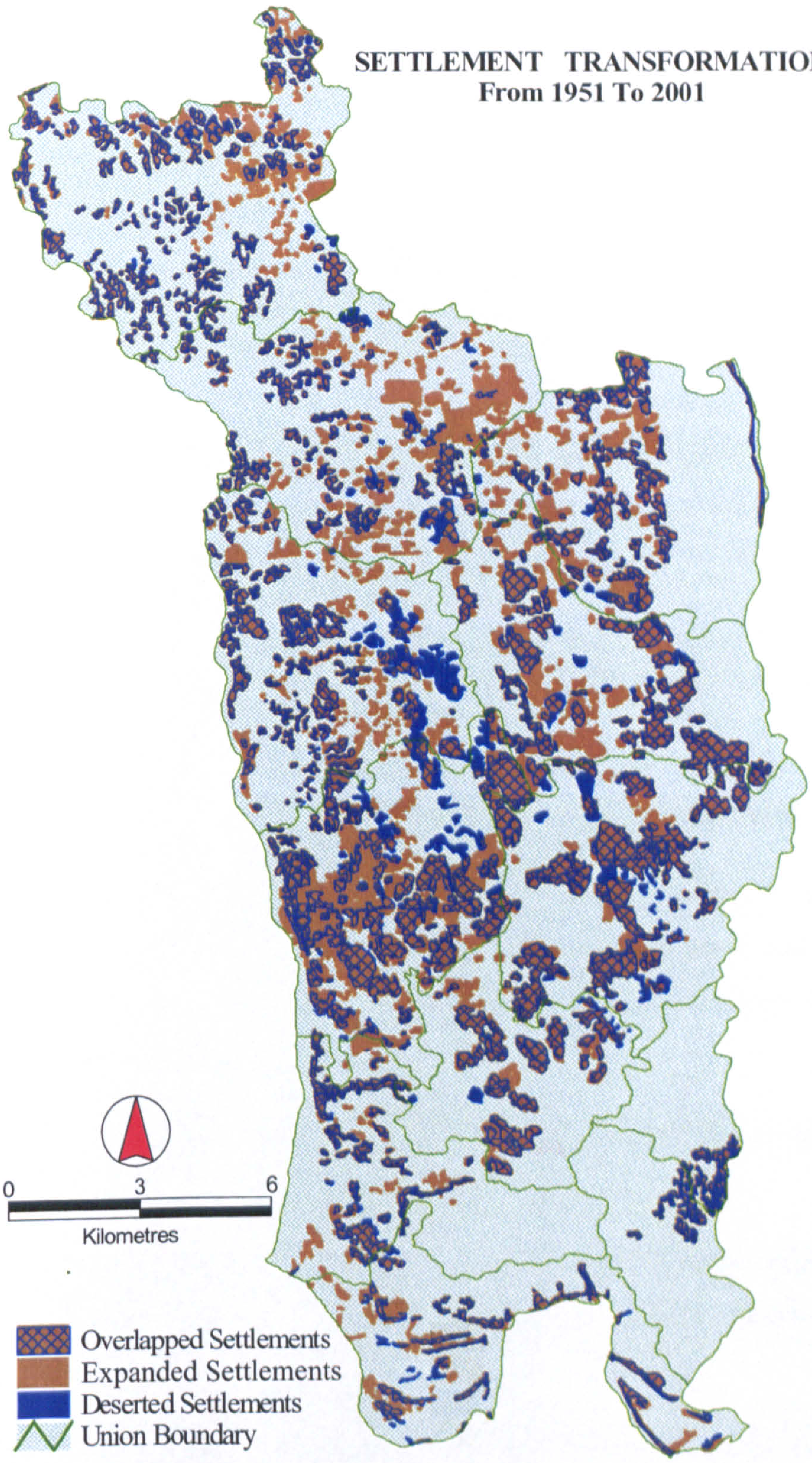


Figure 5-19: This is the overlapped settlement clusters in Savar upazila for understanding transformation flow and concentrations of human inhabitants during 1951-2001.

(2) **Settlement Erosion:** Due to river bank erosion, mainly around the Dhaleshwari River.

(3) **New Settlement:** Settlements expanded in completely new areas. For example, Amm Bagan of Bara Oalia mauza. In the past, it was either on orchard or an agricultural land.

(4) **Settlement Rejuvenation:** New settlement on former settlement sites, for instance the current Musurikhola is not the same as the former settlement of the same name. As imageries show, in the 1950s and 1960s, due to massive shifting of the nearby meandering river, the adjoining settlements were washed away, but the in 1980s and 1990s, after the river retreated, a completely new set of settlements expanded on the *kandi* areas. But the name remains as Musurikhola mauza or village.

(5) **Settlement Redevelopment:** Some rural settlements have been acquired by the government for the building of new urban settlements. The University Town is on the site of such an old rural settlement.

(6) **Settlement Destroyed:** River channel shifting is mainly responsible for this.

(7) **Settlement Deserted or Abandoned:** Due to religious factors, some settlements were forced to evacuate as an impact of the Pak-India war in 1967. Many Hindu refugees moved to India after selling and/or exchanging their lands in the interests of future security.

(8) **Settlement Acquired:** Land acquired by forcing people from land, for example Savar Dairy Farm.

(9) **Settlement Split:** By construction of national highways through the heart of the villages; the Savar Union part of the Dhaka Aricha highway has several examples of this.

(10) **Stationary Settlements /Constant Settlement:** On *kanda* or *dia*, there is no way to expand as there is no suitable land.

(11) **Settlement Compactness:** Increasing the population on a confined territory, building new settlement on a already crowded area, and settlement rising vertically in multi-storied buildings. Amin Bazaar and Kaundia unions are examples.

(12) **Settlement Looseness:** Decrease of population in a confined territory. If local people understand that their land might have a chance of being acquired by the government, or any other organisation, the density starts to fall. For example, due to proposed Ashulia Model Town, the population very close to that area has started falling.

(13) **Settlements Merged:** In some places scattered settlements have been merged over time and expanded into each other. Gokulnagar is a classic example.

(14) **Settlements on occupied land:** Some government or common resource land (*khas* land) has been occupied by local interest groups. For example, *khal* and river embankments (part of the river) have been filled up with new settlements constructed without permission of the government and with the help of corrupt officials.

(15) **Settlement Status Upgrading:** In Savar some rural settlements have been upgraded into *paurashava*, and they are suppose to get municipal facilities by definition, but in practice the local municipality only dispose of waste materials on an irregular basis. Local councils give their main attention to improving *katcha* roads to *pucca* with a very limited resource and in an uncoordinated way.

(16) **Settlements on water:** I observed that some people spend their time on board boats with their entire family. These boats are in effect permanent homes on the move. This group is known as the *Bay'dey* Community. As Bansi River is a perennial river, so this community is also visible in the study area's water bodies. Their status is not by definition a rootless or homeless community, but financially they are in the lower economic class of people. This is their way of life from generation to generation. The female members of the family normally conduct a house-to-house ferry business in the local community, and this community is highly female-dominated.

They travel from one river port to another for their business as a large group (not as single families).

(17) **Underwater Settlements:** There are some settlements used only during the dry season. These settlements are very temporary and their purpose is to protect agricultural fields, and brick-fields. In the wet season, these settlements go underwater for several months and are not visible from space at that time.

(18) **Elongated Settlements:** In southern Savar, the activities of meandering rivers help to expand some of the settlements due to the retreat of the main channel. Some settlements on the natural levée (*kanda*) have been elongated in a band. Saturated settlements may have scope to expand as a result.

(19) **Rectangular Exterior Settlements:** This feature of settlements was frequently seen on the chala land around the big *pukurs* mostly excavated during the 6th to 8th century. There are at least 40 such settlements found in the 1950s-1970s images. The major characteristics are of settlements built up all around the *pukurs* like a square frame. On *chala* land, the inhabitants stored rainwater during wet season and used it all year round for homestead purposes. After introducing shallow tube-wells in Savar in 1970s and their spread in 1980s, the dependency on *pukur*-water was reduced. Some of the ancient *pukurs* have now disappeared by earth filling, as seen on recent images, mainly in the Savar Paurashava area as the land is now very valuable.

(20) **Ribbon Settlements:** The settlements around a road have expanded in a strip and these can be named as ribbon settlements.

(21) **Basti:** These are shanties and resemble urban ghettoes. In Savar upazila Aukpara *basti* is one of the most important examples in this kind. These *basti* people have been forced to move from the capital city and then rehabilitated in Aukpara mauza. In general *basties* are built on government *Khas* lands or on illegal lands occupied by the local *mustans* (musclemen) or ring leaders.

The settlement can also be classified based on the following characteristics.

(1) Infold settlements, enfold settlements and unfold settlements:

The settlements can also be classified as **infold settlements, enfold settlements** and **unfold settlements.** Some relatively big *chalas* or settlements in the paurashava, where density of population is very high, are expanding inward and can be termed 'infold' settlements (like in Kaundia Union). The settlements have no way to expand outward but can comfortably expand inward. 'Enfold' settlements are located on *dias* and *kandis* while 'unfold' settlements are located on open *chalas* (e.g. enfold in Ashulia Union). Enfold settlements have no way to expand horizontally but may rise vertically, because the area is surrounded by the risk of deep flooding (e.g. *chwak*, *chars* and *bydes*), by the land acquisition on behalf of the government (University or Dairy Farm), and so on. When enfold settlements are saturated with dense population multi-storied housing may be started in the area (as in Amin Bazaar Union). The size of an enfold settlements is about one km^2. 'Unfold' settlements have the capability to expand both horizontally and vertically continuously until they reach saturation point. At least one side of this sort of settlement has a corridor for continuous expansion. Unfold settlements are much larger than enfold settlements.

(2) Head and Tail of Chala:

Each *chala* settlement has a head and tail. For example, the location where the *chala* started its earliest habitation can be considered as the head and the backyard orchards are the tail, or in other words, after a significant time, the orchards become part of the settlement. This can be monitored on the satellite images. Sadhapur mauza of Banagram Union is a good example. The southern *chala* is the head where concentrations of homesteads is very high, and in the north the concentration is lower. Why this sort of distribution? The surrounding land of chalas is fertile for agriculture, but the additional river path gave more advantages than *bydes* due to all-year navigation facilities in the north, and that is why early settlers chose this site first and then were forced to go gradually on backyard lands.

This head and tail explanation also helps to understand the other model for each land feature like *Chala, Bydes, Dia, Kanda* and so on. Moreover, the process of urbanisations or dwelling expansion can also be predicted.

The above examples are mainly illustrations to understand the wide meaning of settlements and the process of evolution. If we understand the nature of local settlement, then its pattern of growth can also be predictable and will be useful for understanding the transformation system.

(e) Practical Planning Applications: A Concise Example

Government policies can be informed by using the above information and analysis. The following Figures (Figure 5-20, for part of mid-Savar upazila as zoomed and Figure 5-21 for the entire Savar upazila) are the combined use of remote sensing, GIS and location for primary school planning in Bangladesh. Here I have illustrated the government policy about establishing primary schools in Savar upazila. The basic government guideline is:

> "In order to achieve the target of universal primary school facilities, the current average of one primary school per 3.2 square kilometre should be raised to a level of "**one school per 2 square kilometre**". This requires an increase in the number of schools by about 60 per cent. At present there are about 45,000 primary schools (in Bangladesh). Hence, about 27,000 new primary schools have to be built. (Report of the Task Forces on Bangladesh..., 1991)."

To implement this simple rule, it is necessary to build accurate base line geographic and settlement information. These are:

1. The current or latest settlement area map, to see where pupils live;
2. Land type map so that we can avoid low lying areas unsuitable for schools;
3. Road network for access to schools;
4. Served, overserved and unserved areas of current primary schools under the adopted policy.
5. A buffer zone of 987 metres to map 2 km^2 (see the above govt guideline) areas for the existing primary school.

Using the satellite images or aerial photos, we can fulfil criteria 1, 2 and 3 and a DGPS survey can provide the accurate locations of already existing of primary schools in the upazila, and using GIS techniques we can draw the served, overserved unserved and ultraserved areas. Here:

1. 'Served' means that the settlements are already getting the benefit of a school under the government guidelines;
2. 'Overserved' indicates that at least two or more school buffers are serving a common settlement already;
3. 'Unserved' means that the area is not covered by the government guideline and needs the construction of a new school;
4. 'Ultraserved' means, that a school is serving a very small community.

The following map (Figure 5-21), gives a complete picture Savar upazila. The stripped zones are the served area, and two circles overlapping on the same settlement are the overlapped area. Red settlement zones, where no circles are present, are the absolute unserved areas. In these unserved areas, the government guidelines (universal primary education for all) are important for implementation. Road network and lowland areas (cross hatch) can be also used to determine the final location of new schools in the areas where no school is available. If we want to decide the number of pupils for a new school, an enhanced population density map can be overlapped and utilized easily.

As Bangladesh has no reliable databases, how can the policy makers implement their target? The current example can be a model solution. Otherwise, local influential persons will take decisions without covering the backward or needy zones or corrupt government official will make decisions not on the basis of need but by the influence of bribes or pressure from ring leaders or the so-called elected Union/upazila Parishad chairman/member. Savar is expanding rapidly, so during the conduct of survey the ST index can give an historical idea where the population pressure is higher than the average growth rate. A timely decision can make a credible contribution to educating all children. I also mapped these schools with historical census data and remote sensing images. Some of them give a unique opportunity to understand school expansion in the upazila. But due to space limitation I cannot show all of them. Moreover, the progression of settlement transformation concepts helps to understand the future direction of expansion of settlements based on the past, so the suitable location of a school must also be considered carefully. Establishing a school is not only to serve demand from the current population, but also for the forthcoming generations projected for decades ahead.

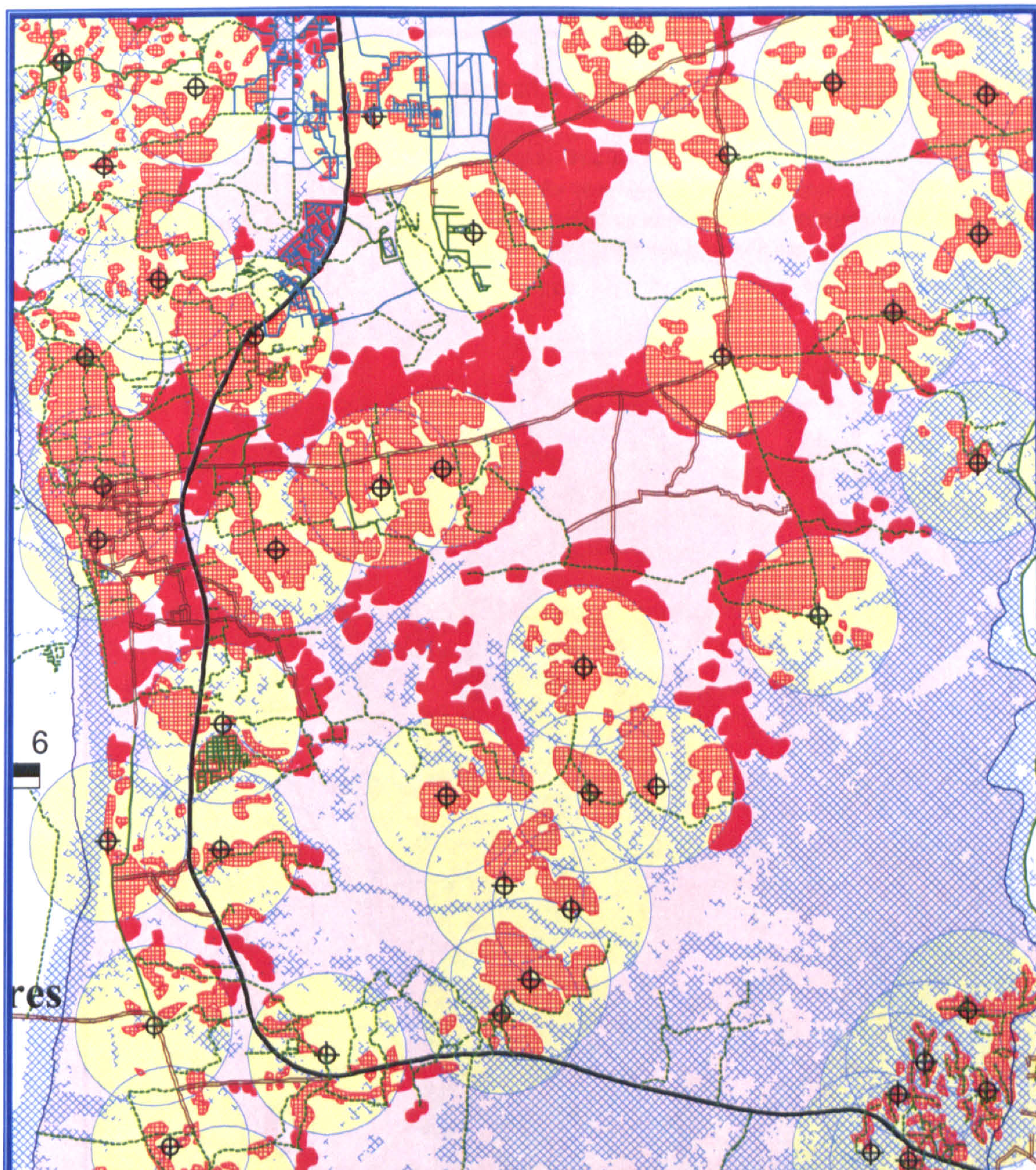
The current example is a simple and very meaningful way of developing a spatial database for policy-makers to achieve certain goal of the government. In this way, the present can contribute in so many decision-making fields for a poor country like Bangladesh in order to optimise use of its limited resources. Currently most of the resources are under utilised or misused due to lack of baseline information and appropriate methods and tools for development agencies involved in Bangladesh like LGED, RAJUK, Ministry of Education and Planning, Paurashava and Union Parishad, Constituency for a Member of Parliament, the Office of the Prime Minister, Local NGOs and so on. Moreover, donor agencies contribute a significant amount of money for various sectors. The example cited here can also be a good tool to demonstrate the real picture in Bangladesh for the implementation of policies.

(f) Roads of Minimising Disparity in ST index

Roads are one of the principal factors explaining disparities of development amongst the unions of Savar upazila. In this regard, the western unions have historically received more attention than the eastern unions despite their similar physiographic scenarios and population density in the pre-development phase. Whatever the government policy and policies of NGOs and the private sector in Bangladesh, in this chapter I have found that only a good road network gives an opportunity for dramatic land transformation around it and also helps to establish a basis for further infrastructure systems. All of the physical and social features are highly linked with the surface transport system. When the society shifted from the river based economy to road based economy, the rapid changes were triggered. As a result we can say that roads are the backbone of development activities. A time sequence of the road economy is interesting. For example:

1. The early road economy was based on the Dhaka-Aricha National Highway since the 1970s. Mainly Savar, Pathalia, Amin Bazaar and Tetuljhora are influenced by this.

2. The secondary road economy is based on Nayarhat-Kaliakoir Highway since the 1990s. Mainly Dhamsona and Yearpur (partial) have been influenced here.



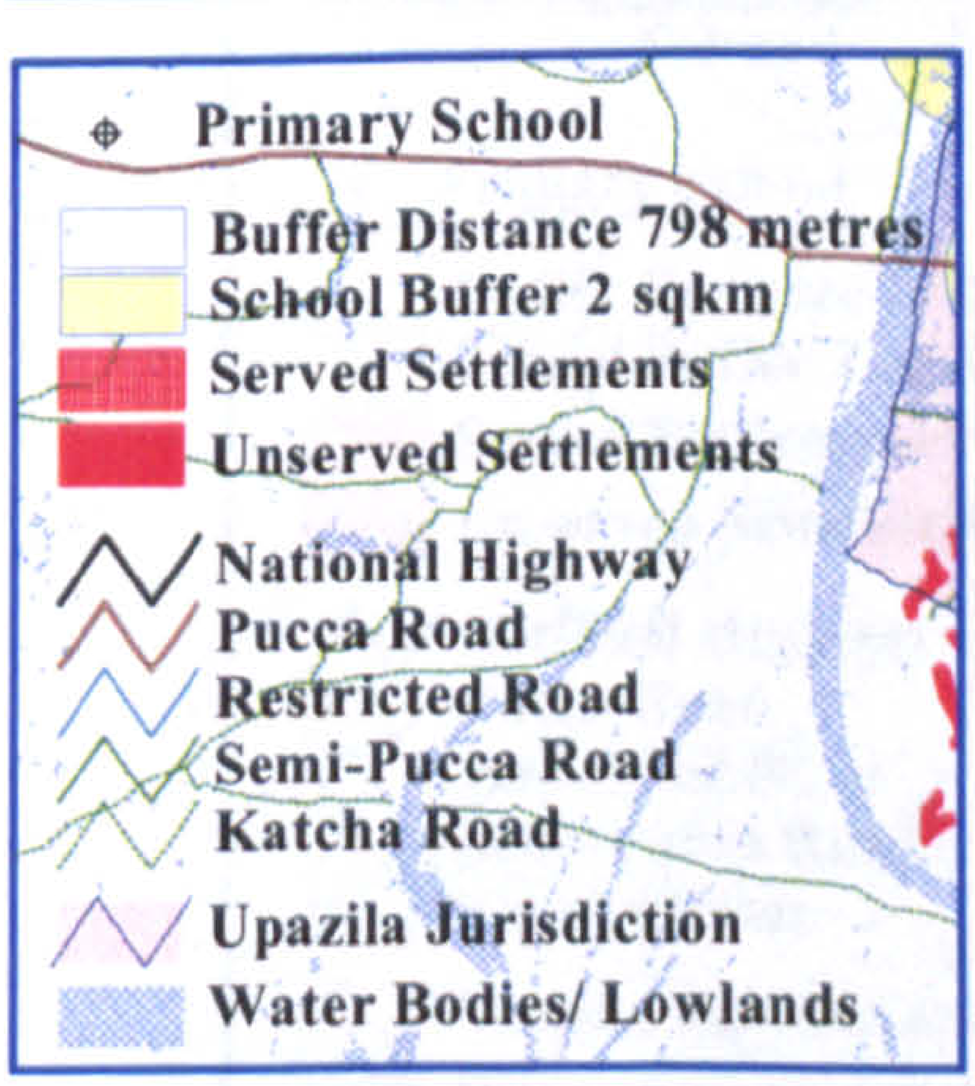


Figure 5-20: Primary school mapping to implement government policy (partially shown here in Zoomed). Circles are two km^2 buffer rings of the existing primary school. Intersected Circle areas are overlapped service area. The solid red zones are unserved communities and should get priority for implementing education policy. The centre of the big circle is the exact location of a primary school, which was surveyed using DGPS techniques in 2001. The road network shows the current communication system with the school. Water bodies and low-lying areas should be excluded for proposed school sites.

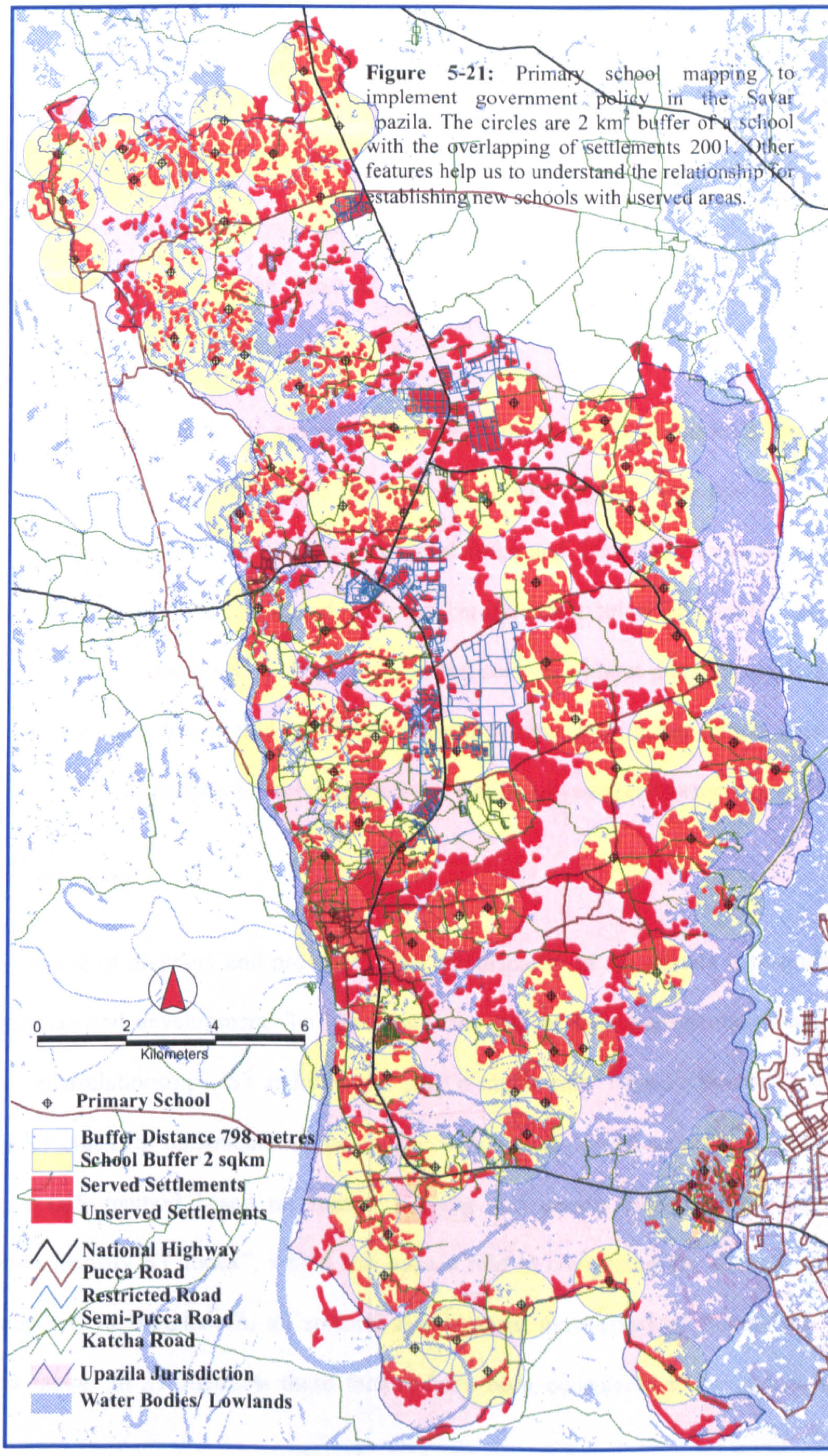


Figure 5-21: Primary school mapping to implement government policy in the Savar pazila. The circles are 2 km^2 buffer of a school with the overlapping of settlements 2001. Other features help us to understand the relationship for establishing new schools with userved areas.

3. The tertiary road economy is based on Dhaka-EPZ Highway since the year 2000. Mainly Ashulia and Yearpur have been linked to this new economy. Also Dhamsona has been linked from the 2nd front using this road.

All of the above main highways contributed through branches to construct many local roads around the particular zone. Most of the ST index has a direct link with the above system as reflected in the surrounding unions.

In the coming years, a highway passing though the Banagram and Biralia will contribute to significant development there. The map (Figure 6-22), suggests some new nodes and link roads in comparison with the existing road links and important nodes or growth centres. The map has been produced with the careful observation of remotely sensed images and the GIS methods. A densely populated society without planning is always a burden for a country. We should take necessary policy now, for a better future. This will help to reduce the disparities between unions with similar physical endowments.

5.6.0. Conclusion

Savar is a land of diversity and prosperity. But the disparity in the upazila is responsible for its unbalanced development. To understand the rate of land transformation and the complex interrelationships, ST indexes can play a major role. I have discussed various types of ST index for understanding the change with the support of metadata, including a combined GIS method based on remote sensing and census data, and a "Adjusted Population Density ST Index", which can have a role in comparing the strength of one union another. In Bangladesh, all sectoral development must consider floodibility as a common factor. In ST methods these factors have been considered to be important. A combined method (Figure 5-11) was used to filter the similar categorised unions in the upazila. Moreover, the land transformation is highly connected with the historical population growth rate and its associated settlement features. Both of these were discussed in this chapter in detail. The complexity and types of settlements are also given for understating the pattern of expansion or any sort of change. So the total area, total population, population density, area occupied by settlements, flood free land left for settlement expansion were the central database fields for detecting transformation.

The ST index is also significant for monitoring change over time, either using a particular time interval or with the help of base year data. Both give concise insights into changes at union level in the study area. The entire database has been categorised based on the development factors. These are: predevelopment stage, developing phase and phase of urbanisation. On the basis of the classes, decennial data can be linked very easily with traditional population census databases, while parallel remote sensing data helps to generate metadata for the census and vice versa. Both play a complementary role very effectively. Enhanced census dot maps at the sub-mauza scale are a credible example of high resolution satellite and aerial photos, which are preferable to traditional density maps and may form a more realistic basis for planning.

A case study of to school location was used to show how can we use the results for solving practical problems in the field with the help of government guidelines. The importance of the road network figured prominently here. Ranking methods can also be used to show which area should get priority for the allocation of resources from the central and local government agencies and NGOs.

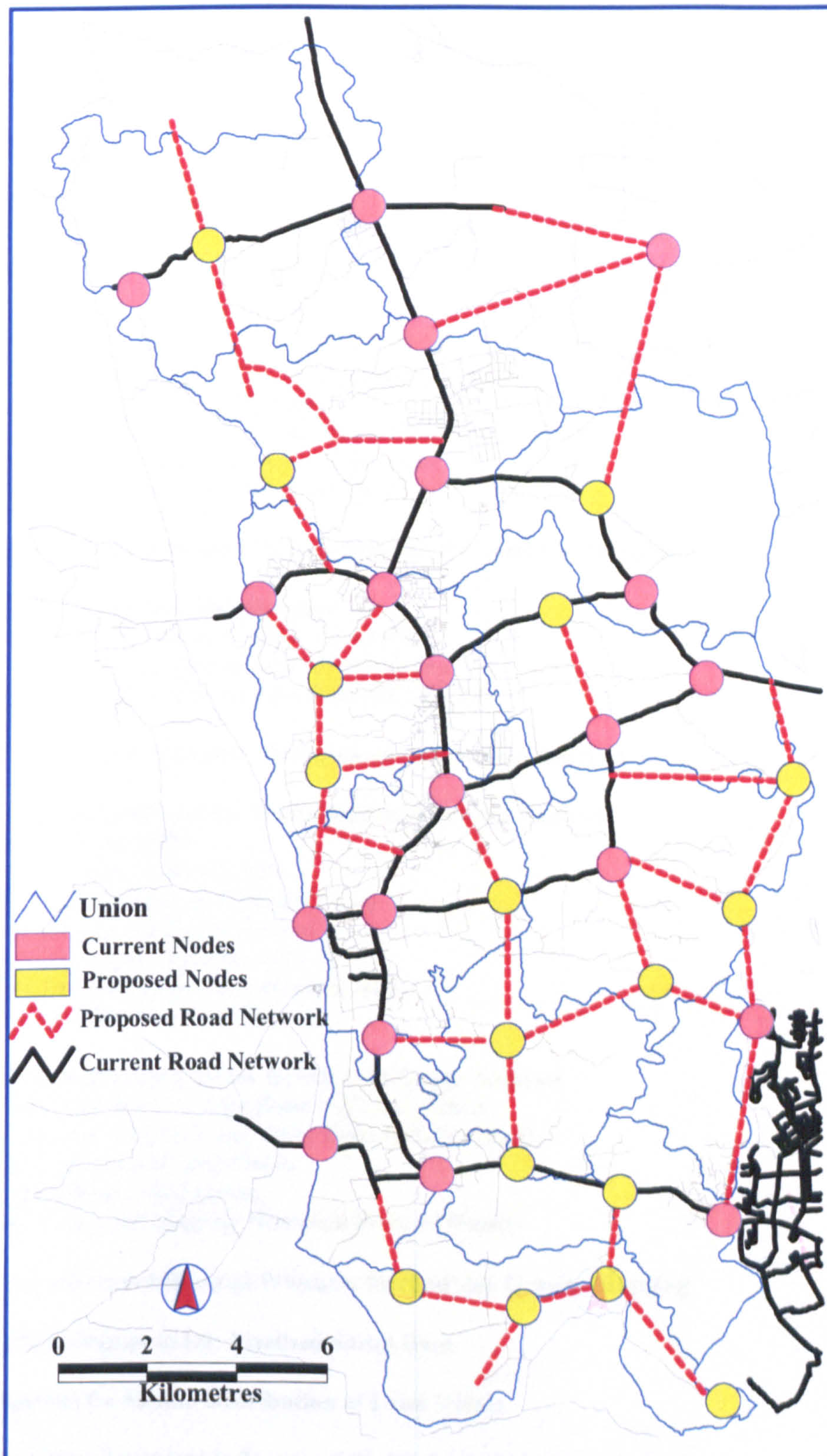


Figure 5-22: The current and future nodes and road links of balanced development of Savar upazila, prepared from remotely sensed images. *(Source: Author, 2002)*

Chapter 6

Chapter 6: Assessing Land Use and Its Weight at Plot Level

6.1.0. Introduction

We have seen how remote sensing can help understand and interpret the land transformations and also how the interpreted remote sensing data can play a significant role to enhance and contextualise population census data. The previous datasets were mainly used at the feature specific and union levels. Now there is a unique opportunity to plot this information to expand our knowledge base and understanding about the land transformation process in Bangladesh at the micro stage that is at mauza level which is based on plot segments. The Mauza maps are not spatially referenced though are widely available in hardcopy. A very large scale mauza map can be spatially referenced using DGPS technology and verified with high resolution remote sensing images.

There are several primary queries in this chapter. These are:

(1) How a mauza map can be used for land use mapping, monitoring and understanding land transformation, this is mainly a part of methodological and background issues;

(2) We have already seen various high resolution satellite images and their interpretation and applications for various fields of secondary data, particularly with population censuses. But now we would like to see how the local people can explain their knowledge and experience of their village with the help of remotely sensed images through participatory mapping. I will try to show their performance in this regard. So this section will focus on first hand data rather than secondary sources of information.

(3) After acquiring basic land use components from a participatory approach, I will discuss them based on my field experience and interviewing local people. This will give an insight for understanding the mauza.

(4) Then we will see how a land use map can be quantified using various visualisation techniques. If we can quantify, what are the implications? What is the role of remote sensing data in this approach? Is it possible to pixelise social data?

So, in the previous chapters, I have integrated remote sensing data with secondary sources (e.g. population census) verified from the field. But now I will use the primary data collected from the villagers and during fieldwork and integrate it with the statistical and image processing approaches.

6.2.0. Methodology

There are several methods used in this chapter. The primary and the most important technique was to develop a dataset as GIS attributes at the plot level. The data were collected for this from both primary and secondary sources. To match this data with the georeferenced images, I had to follow several steps to integrate both. Later I calculated the X-Y coordinates and centroids of each plot of the GIS attributes. The main foundation of the datasets was a participatory approach, and using this method I have mapped the land use pattern of the case study mauza. Later I integrated the collected social data with remotely sensed images. In this section, the main steps are discussed and some of them will be discussed with further details in the relevant forthcoming sections.

(a) Developing Datasets for a Mauza Map

Mauza maps are very suitable for adopting modern approaches such as GIS systems and the advanced mapping technologies. Every plot is marked with a plot number, and every mauza has been on the Jurisdiction list or has had a Geocode number since the beginning. For integrating all the information from the primary, secondary, GIS and image interpretation techniques, a comprehensive dataset was developed for each plot during the field survey. Here, I will give a brief description by way of illustration. I collected field data on the land values of plots for 1951, 1961, 1974, 1981, 1991 and 2001, but in order to make the Table size small, I will give the example of 1951 and 2001 only. In Bara Oalia mauza there are 1547 plots and, based on each attribute table, an enormous number of maps could be drawn. But I have used only maps which are absolutely necessary for this chapter.

The attributes in Table 6-2 are based on the following:

(1) **GIS Attributes:** Examples are given in the rows (1 to 4) as Area, Perimeter, Internal_ID (Oalia_) and User_ID (Oalai_ID). Area has been calculated in metres. Therefore, the area is in metres^2 and length is in metres. The internal ID is given automatically during cleaning and building a polygon while the ID was allocated based on the plot (daag) number.

(2) **Avenue Script:** The X Y coordinates have been calculated (rows 5 and 6 of Table 6-2) from the Arc Avenue Language Scrip based on the Lambert Conformal Conic projection parameter for Bangladesh. The X Coordinate indicates Longitudinal Graticules while the Y Coordinates are Latitudinal Graticules. The adjoining XY position is the location of a centroid of a plot or polygon.

(3) **Field Data and Experience:** I conducted a very intensive field survey mainly for two reasons: one, to get the plot information from the field which cannot be extracted from the RS image directly, for example, the name of a village (row 8), the location of any local infrastructure and the name and type (row 9), school names, NGOs, bridges and so on; two, to interpret the image based on the field experience. For example, I had no idea how to interpret complex land types in Savar, but after ground truthing, it became very straightforward as to the meaning of any pixel of an image. This experience also helped me to apply my knowledge for the historical CORONA and aerial photo interpretation.

(4) **Survey Attributes as Daag (plot) number:** In Savar the two major mauza surveys (CS and RS) were implemented in 1915 and 1975, based on plot level surveys in

the earlier decades. All the plots were marked with a unique plot ID. In the GIS attribute table, I used both the CS daag number (1-1288) and RS daag numbers (1-1547), because 17% of the total land has been fragmented in this time. Using GIS, maps are now visible with unique Ids, with compatible attributes. For example, the CS in 1915 daag 1232 is now RS 337. So we can use both pieces of information at the same time. This helps monitor the history of a plot and its owners. In a few cases, the villagers were not ready to tell me their plot/daag numbers as they thought I came from the government to acquire their land. I circumvented this problem with the help of local *matabbars* (leaders) so that they could put their trust on me. A request for a plot number by an unknown person is a very sensitive issue in rural Bangladesh.

(5) **Land Types:** Bangladesh has various land types based on inundation conditions. As already mentioned, these are: highland, medium highland, medium lowland, lowland, very lowland. I have used a code for each plot in numeric, land type name and the local topographic name.

(6) **Land Unit Calculation**: Land area per unit was calculated based on Decimal (the term is widely used locally and does not carry same meaning of decimal in English) unit. In general, the GIS develops its database in metres, but I converted these into local land record measurement units. For example, the area of a plot is locally maintained in Decimal (one 26^{th} part of a *Bigha*) land, so I converted the $metres^2$ into Decimal. The standard land measurement units and their conversions in Bangladesh are in Table 6-1.

Table 6-1: Table shows the common land measurement units in Bangladesh.

1 Decimal = 40.468564 $metres^2$	**26 Decimal = 1 Bigha**
1 acre = 4,046.8564 $metres^2$ = 4840 $yard^2$ = 100 Decimals;	
1 hectare = 10,000 $metres^2$	**1 km^2 = 100 hectare**

Source: Information collected from the local Amins, 2001

(7) **GIS Attributes from Remote Sensing**: Information interpreted from image data was added to the GIS database. The plot datasets have been made more practical after adding new land system parameters by interpretation of aerial photography, CORONA and high resolution IRS-1D satellite images. Here I have appended several types of information, such as land use, for instance, the location of settlements with homestead vegetation, forested plots, water bodies (e.g. rivers,

khals, beels, pukurs), infrastructures of JU, *katcha-pucca* roads, *eyeels* and extent of land types, and the boundaries of soil series. These values were recorded as a decennial series.

(8) **Secondary Data Sources**: I used secondary data to make the plot-to-plot information systems a base line for environmental and development data. This was included with the help of remote sensing. For example: the Bangladesh Soil Resources Development Institute has identified various soil series based on the micro-climate of the soils at the upazila level. I added this information from the upazila level to the plot level. This could be helpful for local farmers as a soil nutrition and management guide for the better understanding of agricultural land at the plot level, which has never been explored before.

(9) **Land Value Data**: The data acquired regarding land values has a massive social and development significance in the study area. I verified the land registration data, from the land registration documents of the local people /land owners, those who helped me spontaneously, local land *daalal* (brokers) and local representatives or members of grassroots union councils. Through interviewing key persons, I got significant information on land values and how the focus of land has changed regularly, and which factors have been important. I got a very detailed picture of land values in taka, since 1951. In order to avoid the inflation within the mauza boundary, I used a percentage method where the value of a village is considered as a constant of 100.000 from (rows 25 and 26) 1951 to 2001. It was then very easy to map the high land values areas and to make comparisons between decades. Using participatory methods, I classified the land value zones of each village (rows 19 and 20). Here, the local villagers classified their land by their own understanding of land values. Land prices were collected at a per Decimal rate (rows 21 and 22) from the field as well as from the land registration office. I also calculated the total values of particular plots based on per Decimal values (rows 23 and 24).

(10) **Population and Households**: Using visual observation during the field work, I judged the rough social status of a household for 2001. The method was very simple, *pucca bari*, *tinner bari* and *katcha bari* were generally classified as high class, middle class and low income class respectively. However, it was not straightforward in some areas. For example, some high class families prefer to stay as *tiner bari*, even though they have all standard facilities in their house. In that case, personal judgments have been used. It is of course embarrassing to ask any household head about their income since such questions are treated with suspicion.

The number of households and total population in a plot were also collected (see Rows 29 to 34).

(11) **Crop Calendar**: This was the most important factor for centuries in the study area as the total economy was dependent on the primary economic activities, mainly agricultural products. From the field based study I have developed a comprehensive crop calendar with transitional history of individuals of the study mauza. It has had a significant variety of agricultural and local fruit production, either for three seasons, or for two seasons or for a single season. The seasons are *Prak-kharif* (March-May), *Kharif* (June-October), and *Rabi* (November-February). I spoke to elderly farmers in order to draw out the cropping practices of past decades and also the farmers working *in situ*.

Hundreds of additional columns can be added as attributes of GIS from the field survey to the remote sensing interpretation techniques. With the help of these databases, an in-depth understating of land transformation can be monitored, evaluated and the local complexity of land and its interaction with population pressure assessed.

During the field work, I arranged interviews with key informants and local people. Also, a questionnaire survey was conducted (Table 6-3) in order to get some of the above information and verify the remote sensing and census data.

(b) Geo-correction of Mauza Map

For conducting the DGPS survey, I used the following features for geo-correction of all images based on the GCP data (see also Figure 6-1). For instance, to locate the mauza boundaries, I pursued the following steps in order to geocorrect the CORONA and other images. These are:

(a) **In the field:** The following method has been used in the field to identify the ground control points based on the Mauza map.

- find out the location of a site on the CORONA image with the help of local key informants;

- Identify the plot (*daag*) number from the local key persons and keep a note of that;
- Mark the plot number on the Mauza Sheet *in situ*;
- Take the GCP reading of the eyeel of the plot using DGPS (Differential Global Positioning System) and mark the position on CORONA hardcopy maps;
- Keep photographic and/or video evidence of the plot and marking photos using the plot number so that the land use and field situation can be categorised and tagged later.

Table 6-2: Basic database structure and attributes in GIS of Bara Oalia mauza, in this instance for 1951 and 2001.

Sl.	Number of Fields for 1951 and 2001	Value / Class/ Name (Example 1 of 1547 plots)	Value/Class/ Name (Example 2 of 1547 plots)
1.	Area_Metre^2	1725.08538	43793.86590388
2.	Perimeter	180.776600	1054.008000
3.	Oalia_	1287	961
4.	Oalia_Id	337	1905
5.	X_Coord	2768449.25000	2770757.37500
6.	Y_Coord	680504.37500	680740.59375
7.	Area_in_Decimal	45.96	1082.17
8.	Village_Name	BOALIA PARA	UNIVERSITY
9.	Local_Infrastructure	None	VC Qarter
10.	Land_Type_Code	2	6
11.	Land_Type_Class	Low Land	High Land
12.	Local_Type_Name	Boro Jomi	Chala Jomi
13.	RS_1975	337	1905
14.	CS_1915	328	1232
15.	Soil_Series_SRDI	Melandaha	Tejgaon
16.	Soil_Unit_ID_SRDI	13	1
17.	Landuse_51	WB : Perennial Water	HH : Bari with Veg/Orchard
18.	Landuse_01	Agri: Boro / Rabi Crops	JU : Staff Residence
19.	Plot_PRS_51	E3	X3
20.	Plot_PRS_01	F3	X1
21.	Taka_51_per_Dec	4.0	1.0
22.	Taka_01_per_Dec	1000	100000
23.	Plot_Value_Tk_51	184	1082
24.	Plot_Value_Tk_01	45960	108217000
25.	Plot_Value_%_51	69	405
26.	Plot_Value_%_01	1	3211
27.	Crop_Cult_51	None	Shaal Forest
28.	Crop_Cult_01	Boro	Prak-Kharif/Kharif/Rabi
29.	Popn_01	0	10
30.	Popn_51	0	0
31.	HH_Status_51	None	None
32.	HH_Status_01	None	H
33.	HouseHold_01	0	5
34.	HouseHold_51	0	0

Source: Image interpretation, GIS Approaches and Field Survey, 2001

Table 6-3: A sample of Field Questionnaire

Plot Level Village Survey in 2001 (Mauza Map Based /Mainly for Settlement Area)

Plot Serial Number:

Name of Respondent/s	Age	Sex	Occupation	Years in Village

If Migrants- How many years ago and from where?

Village: Para (New Name/Old name-if any):

Mauza Name: Sheet number: Code:

Plot/Daag Number - CS: RS:

(*Plot location must be marked on the supplied Mauza Map or Sheets*)

Category		1951	1961	1974	1981	1991	2001	Comment
Land-type (H, MH, ML, L, VL)								
Local Topographic Name (e.g. *Naal, Chala, Tek, Byde, Beela*)								
Duration of Inundation (Months, e.g. July-Sept)								
Number of *Ghars*	A. Pucca Roof							
	B. Tin Roof							
	C. Other Roof							
Number of People living on the plot								
How long family members have been living on this plot (oldest one)								
Ownership (Private/ govt/ *khas*/ Commercial etc.)								
Land value ('000 taka/Per Decimal) Note: we will count inflation later on								
Main Influencing factors for change /no-change of Land-value/Land-use								
Main Profession (in general for the inhabitants (agriculture, fishing, industry, service etc)								
Social Class of the inhabitants of the plot in general (H, MH, ML, L)								
Land use (every detail) (current land use must be drawn clearly on the provided map during field work)								
Vegetation/agriculture (Homestead garden / Forest and Crop 1, Crop 2, Crop 3)								
Any Remarkable Infrastructure/s (e.g schools, bridge, deep tube well)								
Utility lines (Electricity, Gas, Sewerage etc)								

Did any problem occur during data collection? If yes, PLEASE specify:

Signature: **Name:** M.S. Rashid **Date of Data Collection:**

(b) In the Lab: After getting the detail field information and sketch on the maps, the images have been processed in the lab in order to:

- Find out the desired plot on the image/mauza map and same DGPS polygon in the coverage;
- Locate an eyeel corner and the same polygon corner from the both media;
- Use vector to image for geometrical correction method based on both the selected corners from the image and mauza using DGPS coverage of the same plot;
- Take a suitable number of DGPS plots for geo-registration of the CORONA image of a mauza.
- Match with the local (*katcha/pucca*) road network and water bodies surveyed by DGPS methods with the corrected images and, if there is no mismatch, then the geo-correction is accepted.

Feature Identification: On the high resolution image, there are several types of features which can be used for geo-correction but these depend on the stages of development of that area. For example, a feature available in the predevelopment phase may not necessarily be available in the pro-urban phase. So I took special care with that. The remarkable features visible in the decennial images identified during the field work are given below:

(1) **Predevelopment Features:** These features are linked to natural boundaries and phenomena, for example, *eyeels, pukurs, khals,* rivers, *katcha* roads, archaeological sites, plot boundaries, *byde* margins, isolated palm trees and grid of *kathal* trees etc.

(2) **Prodevelopment Features:** Most of the features at this stage are modern phenomena with clear geometric shapes, like national and regional highways and

pucca roads, embankments, prominent buildings and infrastructures, monuments and interesting sites, bridges, planned farmyards, modern housing societies and towns, brick-fields, etc.

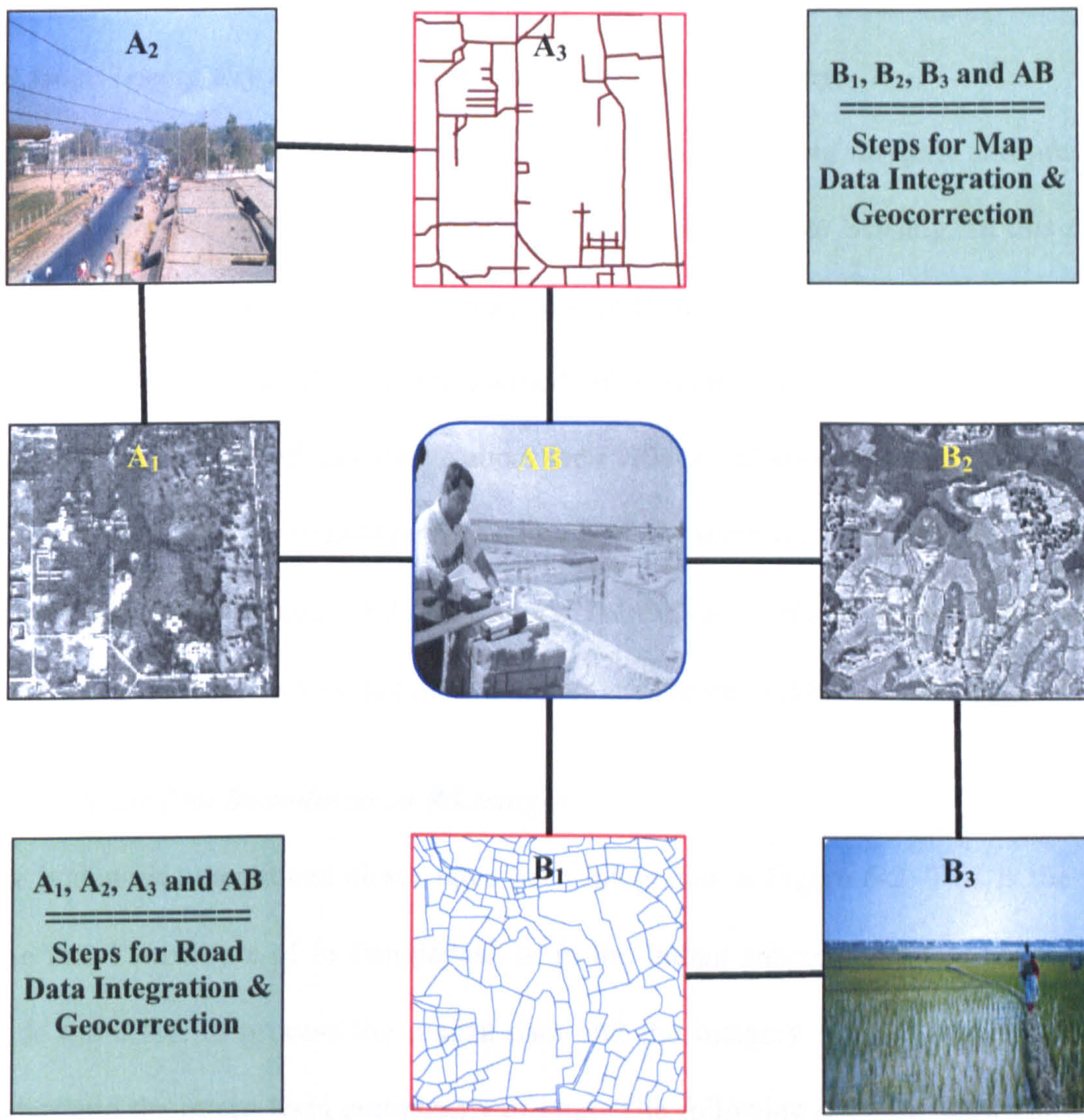


Figure 6-1 Major steps are followed for geo-correcting the mauza maps and prominent features like road with the help of Global Positioning Systems. Here A_2 and B_3 indicate the field investigation, A_1 and B_2 are the images used for identifying a particular feature, and B_1 is the mauza map of 1975 and A_3 is a road layout captured by the DGPS approaches shown in the AB frame. Group A is relevant to the Road Network positioning and Group B is responsible for mauza map geo-referencing.

(c) Centroids and 'Georeferenced Box and Whiskers Method'

I ran the ArcAvenue Script to calculate X Y coordinates in ArcView™ (please see Script 6-1) This helped me to find out the centroid of each plot polygons in order to do the further analysis of the generated X Y coordinates based **'weighted land use'** data using Stata™, a powerful statistical software package. The name of the method I proposed for the first time as the **'Georeferenced Box and Whiskers Method'** which will be explained later.

(d) Interviewing Key Informants for Participatory RS Mapping

For interpretation of CORONA and Mauza Maps for mapping the past and present, here the methods used can be termed as Participatory Remote Sensing. In this case, those who are involved with mauza maps due to their personal interest and profession, they were mainly included in this method of interviewing. Above all, the persons should have a very good knowledge about their village and know almost every place in of the village. Key informants performed well while assisted by a small group of their fellow ordinary villagers and were very helpful and interested in participation approaches. This group also had no idea about any planning taken by the authorities.

(e) Integrate Plot Boundaries to RS images

The boundaries mentioned above have been integrated in Figure 6-2. This is the first time that I am aware of in Bangladesh or in the Indian subcontinent that anyone has made the effort to process the mauza data and the imagery in this way in order to understand the micro-level complexity of land. The following diagram shows how the historical datasets have been integrated with the mauza maps. It reflects a jig-saw fit of map and image. Moreover, it gives a history of the pictures taken by the air or space borne sensors and makes the map more meaningful and acceptable for the research community and for historical change analysis. Though the print-outs of the images are of relatively poor quality here, in reality they are of about 2 metres ground resolution.

Script 6-1: ArcAvenue Script for Calculating Plot Centroids

```
' Name: View.AddXYCoordToFTab
' Title: Adds X and Y coordinates of features to
Attribute Table
' Topics: GeoData
' Description: Adds two new fields, named X-coord
and Y-coord, to the table
' of the Oalia_XY active theme in the TOC and fills
the respective fields with
' the X,Y coordinates of the selected points (or all
points if no selection
' is defined) in a point theme. If instead the active
theme is a polygon
' theme, then the X,Y coordinates of the polygon
centroid are calculated. If
' the theme is projected, the output coordinates will
also be projected.
'
' Requires: An active point or polygon theme. This
script does minimal
' error checking and assumes that there is an active
theme.

theView = av.GetActiveDoc
'must be global to work in Calc exp below
_theProjection = theView.GetProjection
project_flag = _theProjection.IsNull.Not 'true if
projected
theTheme = theView.GetActiveThemes.Get(0)

'Check if point or polygon theme
if (((theTheme.GetSrcName.GetSubName = "point")
or
   (theTheme.GetSrcName.GetSubName =
"polygon")).Not) then
  MsgBox.Info("Active theme must be polygon or
point theme","")
  exit
end

'get the theme table and current edit state
theFTab = theTheme.GetFTab
theFields = theFTab.GetFields
edit_state = theFTab.IsEditable

'make sure table is editable and that fields can be
added
if (theFtab.CanEdit) then
  theFTab.SetEditable(true)
  if ((theFTab.CanAddFields).Not) then
    MsgBox.Info("Can't add fields to the
table."+NL+"Check write permission.",
    "Can't add X,Y coordinates")
    exit
  end
else
  MsgBox.Info("Can't modify the feature
table."+NL+
  "Check write permission.","Can't add X,Y
coordinates")
  exit
end

'Check if fields named "X-coord" and Y-coord" exist
x_exists = (theFTab.FindField("X-coord") =
NIL).Not
y_exists = (theFtab.FindField("Y-coord") =
NIL).Not

if (x_exists or y_exists) then
  if (MsgBox.YesNo("Overwrite existing fields?",
  "X-coord, Y-coord fields already exist", false))
then
   'if ok to overwrite, delete the fields as they may
not be defined
   'as required by this script (eg., created from
another script).
   if (x_exists) then
     theFTab.RemoveFields({theFTab.FindField("X-
coord")})
   end
   if (y_exists) then
     theFTab.RemoveFields({theFTab.FindField("Y-
coord")})
   end
  else
   exit
  end 'if (MsgBox...)
end 'if

x = Field.Make ("X-
coord",#FIELD_DECIMAL,18,5)
y = Field.Make ("Y-
coord",#FIELD_DECIMAL,18,5)
theFTab.AddFields({x,y})

'Get point coordinates or polygon centroid
coordinates
if (theTheme.GetSrcName.GetSubName = "point")
then
  if (project_flag) then
   'Projection defined

theFTab.Calculate("[Shape].ReturnProjected(_thePr
ojection).GetX", x)

theFTab.Calculate("[Shape].ReturnProjected(_thePr
ojection).GetY", y)
  else
   'No projection defined
   theFTab.Calculate("[Shape].GetX", x)
   theFTab.Calculate("[Shape].GetY", y)
  end 'if
else 'polygon case
  if (project_flag) then

theFTab.Calculate("[Shape].ReturnCenter.ReturnPro
jected(_theProjection).GetX", x)

theFTab.Calculate("[Shape].ReturnCenter.ReturnPro
jected(_theProjection).GetY", y)
  else
   theFTab.Calculate("[Shape].ReturnCenter.GetX",
x)
   theFTab.Calculate("[Shape].ReturnCenter.GetY",
y)
  end ' if
end

'Return editing state to pre-script running state
theFTab.SetEditable(edit_state)
```

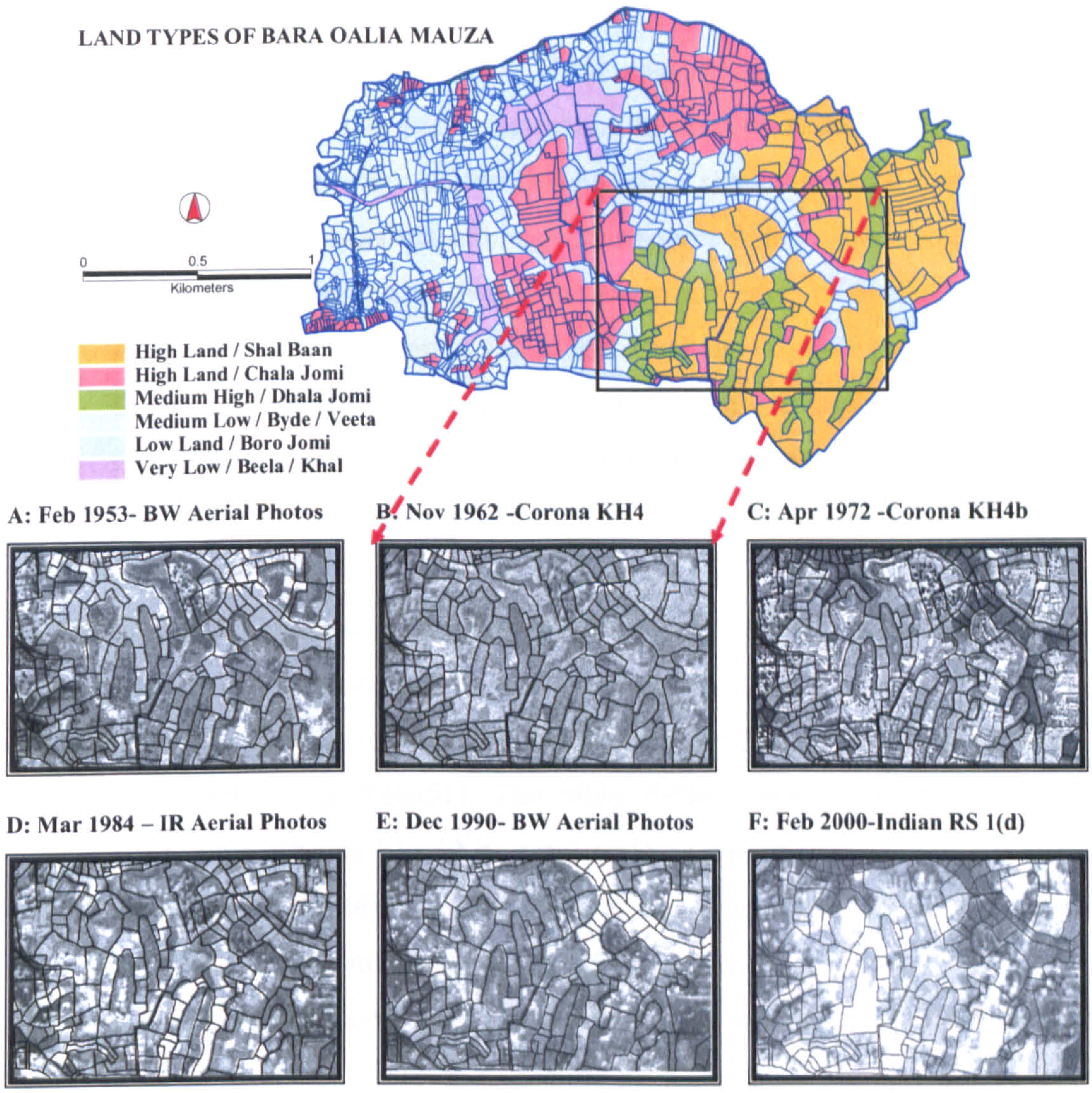


Figure 6-2: Vital features of land types, land use and land cover are straightforwardly identifiable using the interpretation chart of the remote sensing images for the plot level mauza maps; including their changes over time (reduction of resolution and distortion during printing do not show the actual representation of the images).

(f) From Data to Image: Pixelising Social Data

In this section, I will illustrate how to add social data to the imageries. The process requires ArcView™ software to convert in GRID and Tiff or IMG formats and then any remote sensing software can add it as a band. I have used PCI software to do so. All of the steps involved in this process are given below.

Step 1. Open the Oalia *Mauza* (Polygon).

Step 2. Convert Polygon into Shape file.

Step 3. Open the Oalia *Mauza* (LabelPoint).

Step 4. Open at least one Image of Oalia (Oalia.img as Image Analysis Data Source).

Step 5. Cut box image into poly shapes similar to Oalia using Image Analysis properties (by selecting analysis extent and a shape file based mask).

Step 6. Open Image Analysis file as Image Data source file.

Step 7. Convert to Image as Grid file by selecting properties of Spatial Analysis for Analysis Extent (Polygon of Oalia) and Mask (appropriate grid file).

Step 8. Convert a polygon Shape file to Grid file by using image properties and cell size. Then Pick Taka 1951 field for cell values without joining other features.

Step 9. Make active the theme of labelPoint image, and Interpolate Grid from Analysis Menu.

Step 10. In Output Grid Specification, select output grid extent and Similar cell size to any newly created image.

Step 11. From the interpolated Surface, keep everything as a default except the Z Value Field (e.g. Taka51). The other default values are Method= IDW, Nearest Neighbours 12 with power 2 and no barriers.

Step 12. Save Data Set (Grid) as a file and Open it as Image Analysis file and create a pyramid for that. Now as it again as Imagine file.

Step 13. In this procedure, create other land value files of 1961 to 2001 of the same area.

Step 14. Using any image processing software, add all land values containing a 6-band image file.

6.3.0. Issues Involving Land Use Monitoring and Change

After having a general methodology, from this point, I will mainly focus on the land use of Bara Oalia Mauza. But this will not be based on the traditional way of understanding the land and its ever-transforming features between 1951 and 2001. The following sections will follow the major and very central themes which will help us to foresee the sequence of this chapter:

(1) Participatory mapping of land use where CORONA data will be interpreted by the key informants is termed '**Participatory Remote Sensing**' in section 6.4.0 and this will help to draw land use maps for the next sections 6.5.0 of this chapter.

(2) In section 6.5.0, I will try to explain the major components of the land use with some historical and photographic evidence including the detailed context and backgrounds. I will term this the **'General (or unweighted) Land Use'** pattern of Bara Oalia Mauza;

(3) Then I will enter the more complex part 6.6.0 of this chapter, where every land use component will be weighted by land values. Then we will get the numerical basis of land uses for geo-statistical techniques. That means we will be able to see the centre of gravity of the land uses and their historical pattern of changes using centroids and the geo-referenced box and whisker method. In this section we will also illustrate how we can integrate social data into remotely sensed images, which will help to explain the factors responsible for land use changes with a new dimension of understanding interpreted land features. The factors found for change will be shown with weighted components. The entire section will be termed **'Weighted Land Use'**.

It is important to keep remembering the above stages of progression in order to understand the coherence and integrity of forthcoming crucial parts of the current chapter. But before starting the main theme, we need to know some basic issues at plot level. These are examples of CORONA images for recapping some important features, then what are the major influencing factors for change and why we took Bara Oalia Mauza as a test case and a brief background of Bara Oalia, which will help us to understand the context of the villages in the Mauza and relevant issues.

(a) Interpreting from CORONA Data

As discussed earlier, mauza maps have a great and unique potential for use with high resolution satellite images. Figures 6-3 to 6-13 are the typical examples of that. It is visible from the CORONA image that, though mauza boundaries are based on land ownership, the size shape of the mauza gives some special aspects which have not been seen and verified before. Over a century only two mauza map surveys were implemented but neither with the help of satellite or remote sensing images. It has already been proved in the previous chapters that the land in Savar is changing rapidly but there has been no monitoring system for that. Surveying Mauza maps is a very time-consuming, expensive and skilled labour-intensive job; and there are a lot of chances for data to be corrupted or manipulated. Remote sensing techniques can help to overcome these problems and play a neutral but vital role in developing land databases. The benefits of integrating remote sensing with mauza maps and how can it help to help to understand land transformation systems will be discussed later. From the examples we can see several aspects of mauza maps. Here, we used CORONA images, because the photography and the mauza survey were conducted at almost the same time over the study area.

1. **Rivers/Khals Recorded as Personal Land:** It is a very genuine issue that rivers cannot be recorded as personal property. But if we see the size and location of mauza maps then it is clearly visible that a lot of plots owned by the local people are part of the river. Figure 6-3 is located in Ganda Mauza on the Karanatoli Khals. With the help of remote sensing images, we can easily identify the gross negligence and bias of the surveyors towards certain quarters of society.
2. **Small Water Bodies Detection:** Mauza maps have a very significant link to the feature specific boundary where this is not necessarily mentioned on the map. So remote sensing opens a gate to enrich mauza maps. It gives the precise circumstances of a plot and its surroundings. This will help us with environmental impact assessment as well as for the long term. In Figure 6-4 for instance a small water body known as a *doba* is shown. High resolution images can help identify the seasonal changes of such water bodies and the impact on the neighbourhood.
3. **Agricultural Land:** The detection of moisture in the dry season is very significant for agriculture resources development in Bangladesh. Moreover the level of irrigation facilities required can also be assessed (Figure 6-5).
4. **Settlement Locations and Growth:** Mauza maps with the help of CORONA images give a clue as to why the plots were very small in the village. It is a very old village and the plots are highly fragmented. Moreover, the extent of the village was constrained by the surrounding very low land, so the rate of fragmentation was very high on the constant and unexpandable land where the population growth rate

was very high (Figure 6-6). So mauza maps also carry the invisible settlement and land fragmentation histories of villages.

5. **Byde Monitoring:** Bydes are important phenomena for both the predevelopment and development phases. In the predevelopment phase, they had the ability to produce up to 3 crops a year. Figures 6-7 and 6-8 show the shape and size of bydes and their surrounding context. Interestingly, the plot shapes of the mauza maps match clearly with the byde strips. In the developing phase most of the land-fill happens on the byde land.
6. **Large Water Bodies:** There are several large water bodies in the villages studied. These are mainly beels and rivers and these are considered as common resources. Which plots belong to these features and who the owners are can also be identified using the CORONA images. I noticed during the field work that the beels and rivers were recorded as agricultural land due to corruption of the then surveyors. The rate of corruption is ever-increasing in Bangladesh so the updated mauza map will have more problems. If the government verified its land registry using RS data it could recover a significant amount of property for the benefit of deprived communities. Figures 6-9 and 6-10 are shown as examples. Moreover, the historical and seasonal status of the land can also be monitored for this area.
7. **Settlements and Byde Tops:** Figures 6-11, 6-12 and 6-13 illustrate plot sizes around the byde top settlements. Figure 6-11 is a high settlement density byde, Figure 6-12 is medium density and 6-15 is a very low density byde. The sizes of the surrounding plots depend on the density of population.

(b) Impact Assessed on Mauzas during Fieldwork

I have selected four villages for detailed studies on land transformation and its impact assessment at mauza level. The four mauzas were selected based on the following:

(a) **Impact of a large government institution.** A nearby mauza, Bara Oalia, located in the west of Jahangirnagar University has been chosen for that.

(b) **Impact of a municipality** like Savar Paurashava: A mauza, Ganda, located in the south-east selected to undertake this study.

(c) **Impact of an industrial belt** like the Export Processing Zone (EPZ): A mauza, located in the north-west, has been used to assess the impact of the EPZ.

(d) **Impact of prolonged non development** for decades: Bara Kakur is an ideal mauza which has had no direct pucca road network, no development of big installation or government, private or other infrastructures near to the village.

The selected mauzas had almost similar land features and represented all types of land types and their economic importance has been almost the same in the early 1950s. All of them have access to the river directly, the density of population was almost the same and the sizes of the mauzas are also reasonably similar. They are also very close to the criteria I considered and they have no other major influences other than the mentioned indications.

In this chapter I will mainly focus on Bara Oalia Mauza. Bara Oalia mauza in 1950s was part of very rural economy. In the 1960s the construction of Jahangirnagar University and the nearby national highway were important factors for inviting rapid change. Here we can see a pre-development situation and gradual development since then, but among the other mauzas, Ganda always had influence on the Upazila headquarters and its influence was increasing gradually, and the EPZ is a recent phenomenon so we cannot gauge its influence at decennial scale over the last half century. Finally, Bara Kakur has been considered to understand the impact of a village over the time where no development activities have been initiated. After collecting all necessary data of all four mauzas, Bara Oalia is the best example in the upazila of real land transformation using a single mauza.

Mauza based Plot Land Owners extent shown on the CORONA Images

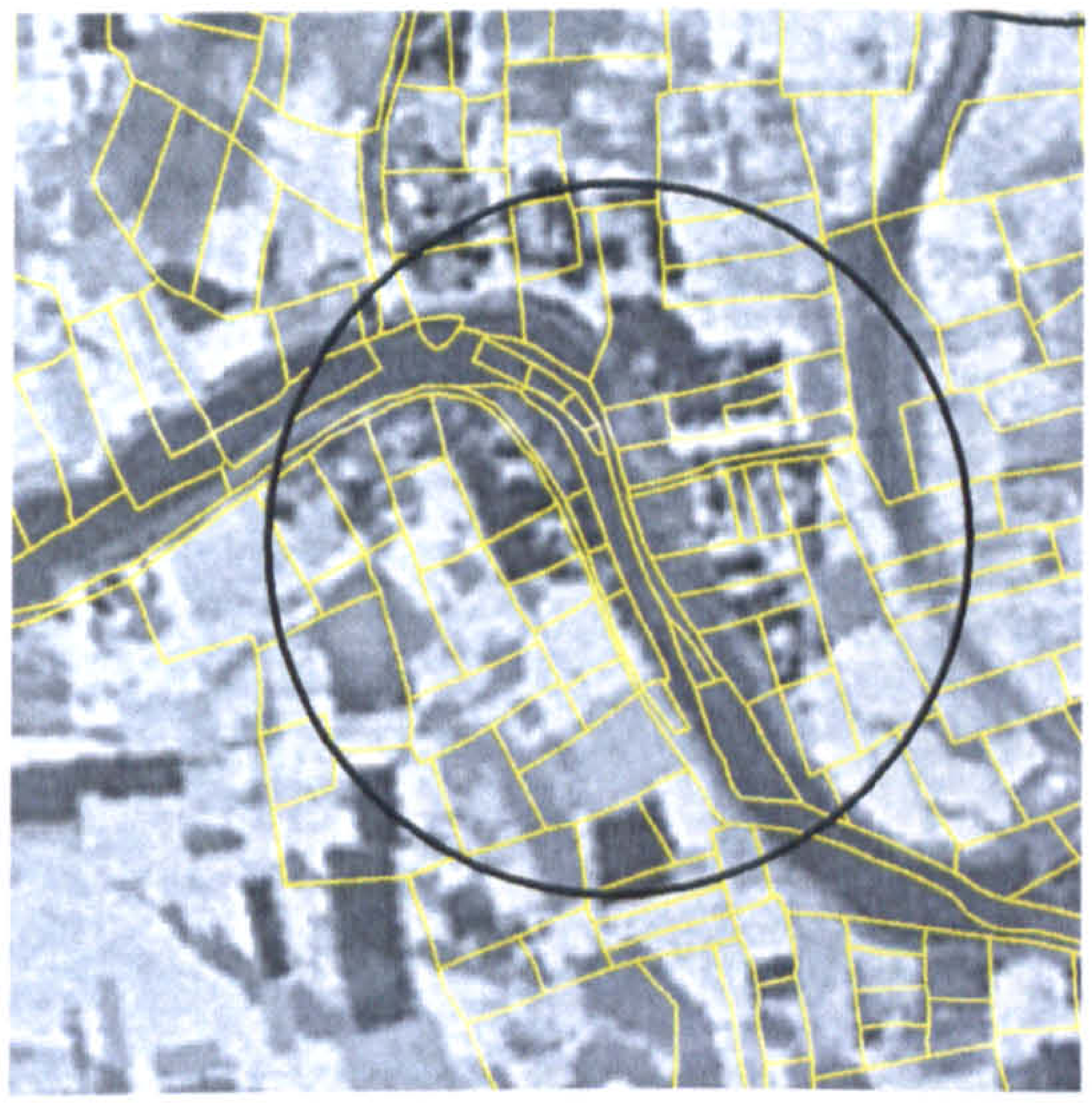


Figure 6-3: River *(Nodi)* Recorded as personal land

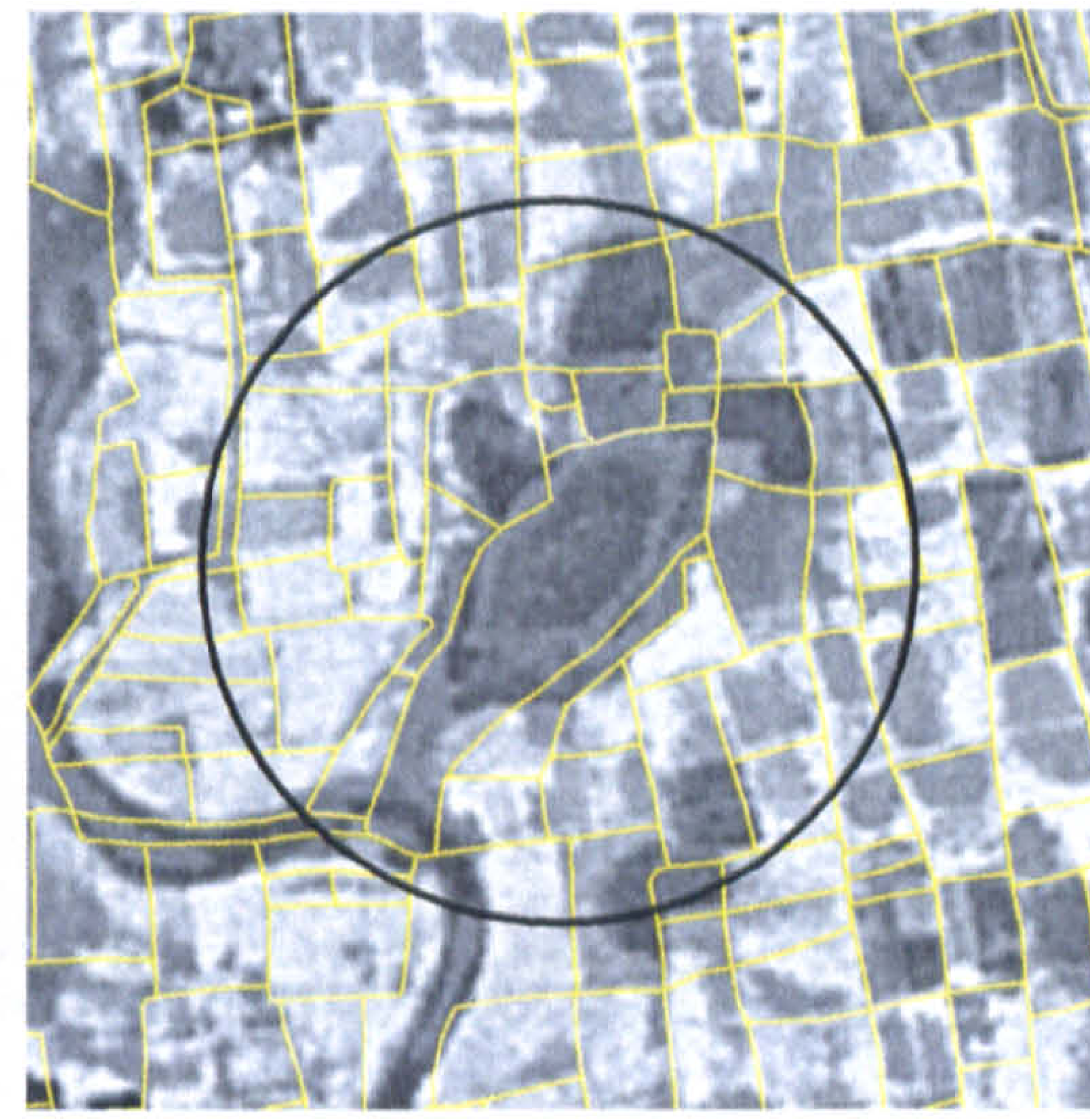


Figure 6-4: Khas Doba, used by local paurashava chairman

Figure 6-5: Chwak land fragmentations

Figure 6-6: Small Household Plot size like Para

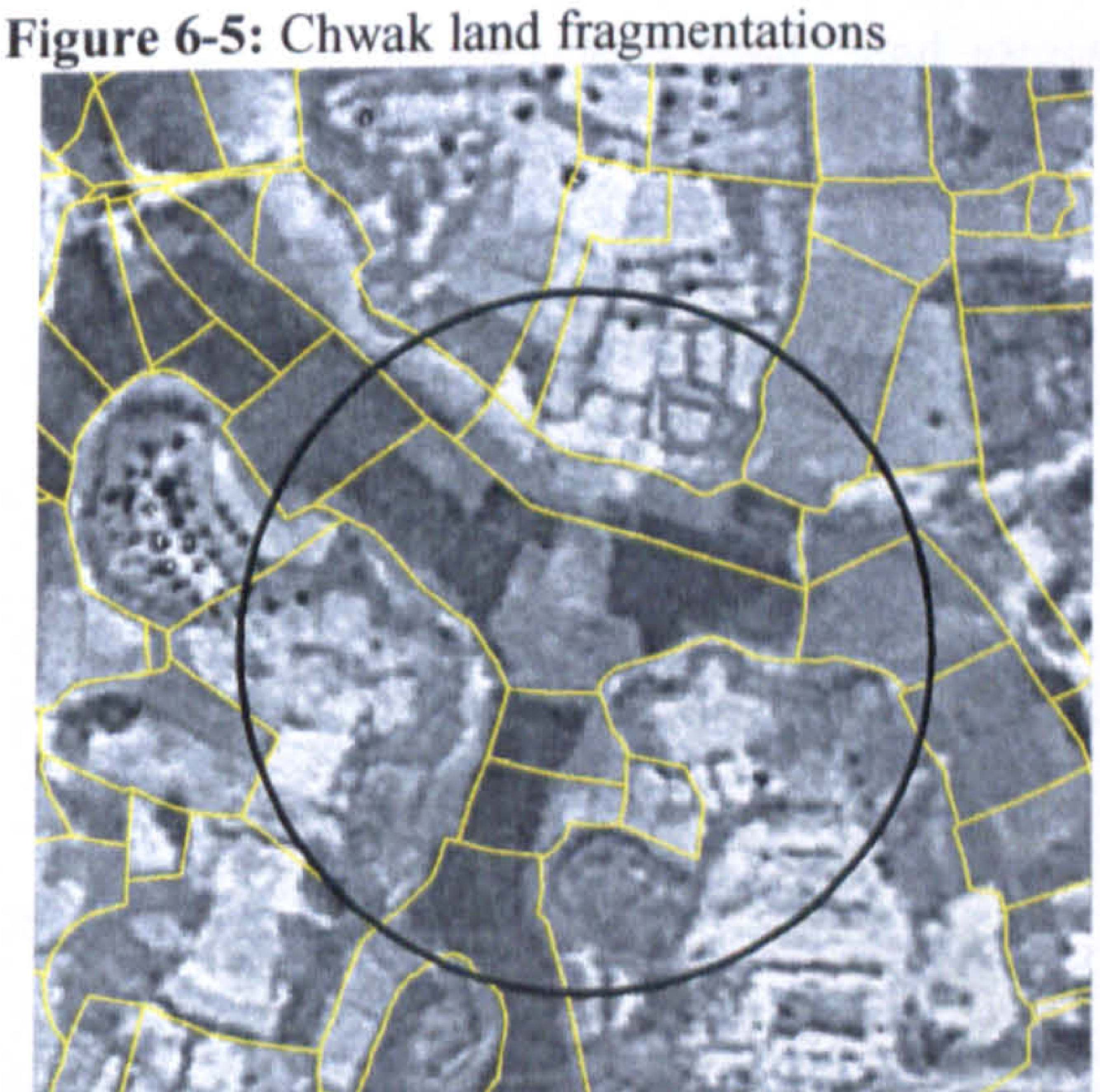


Figure 6-7: Lower byde identification

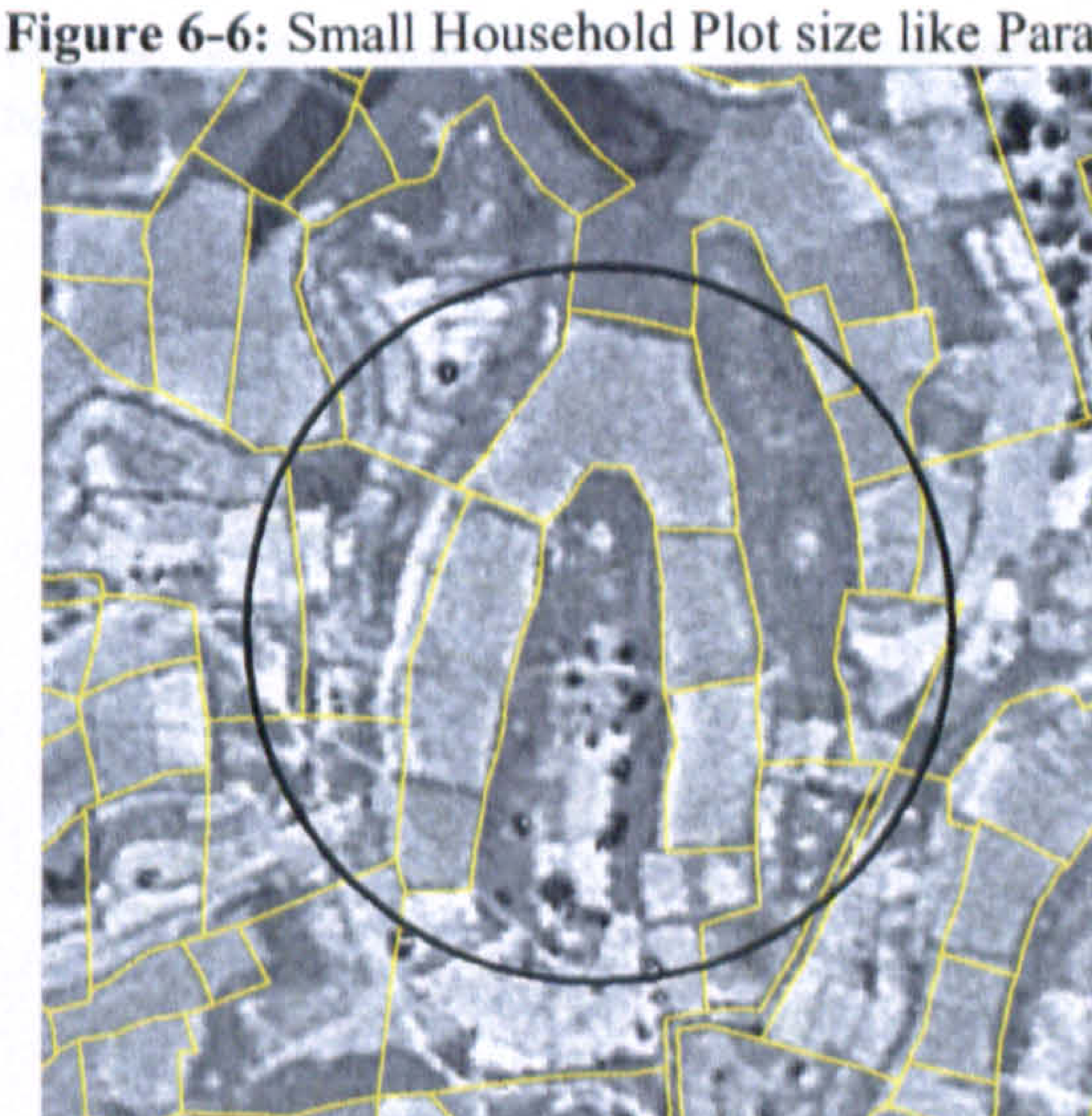


Figure 6-8: Upper byde identification

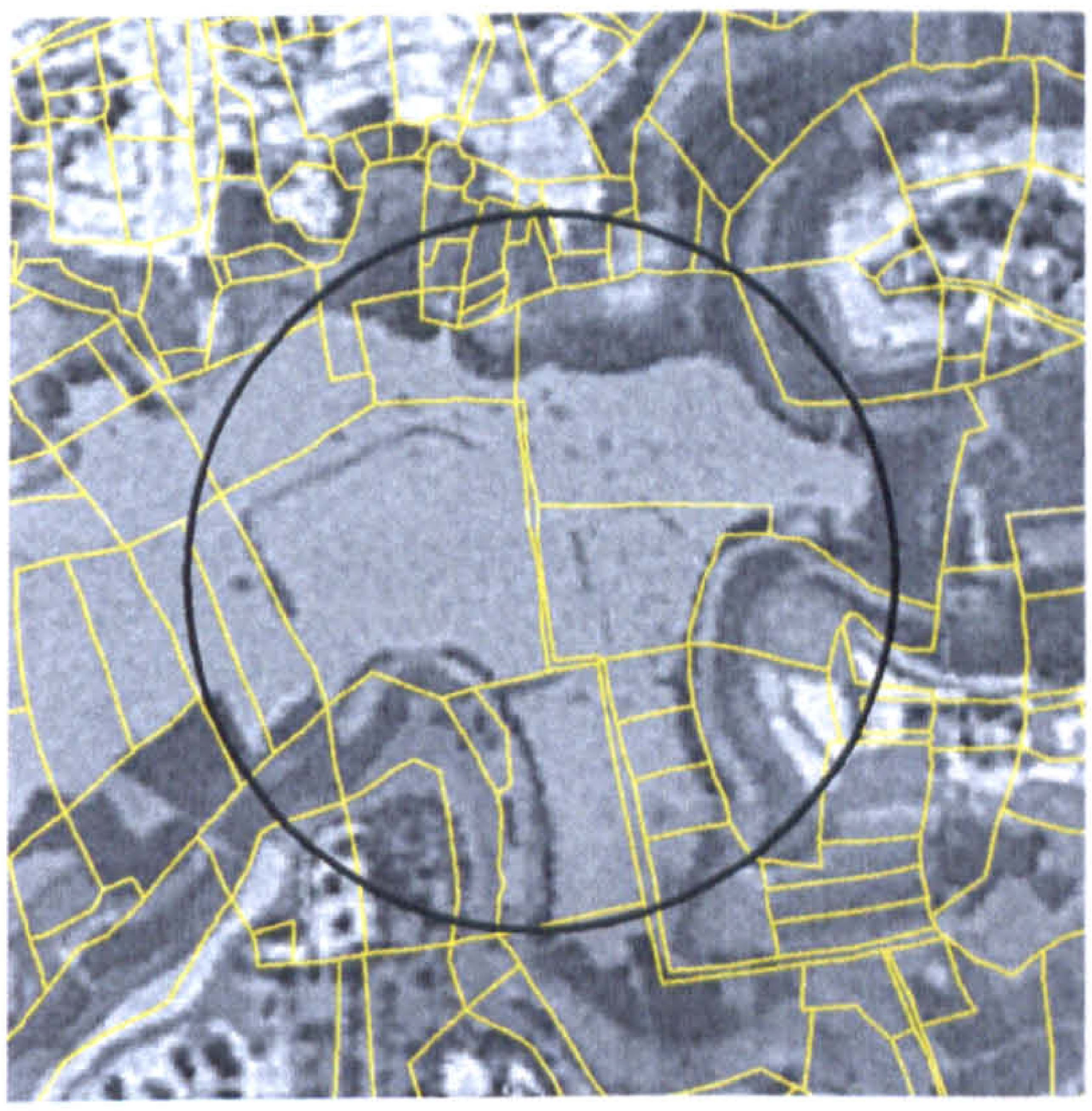


Figure 6-9: Beel recorded as personal property, although it should be regarded as common resource property.

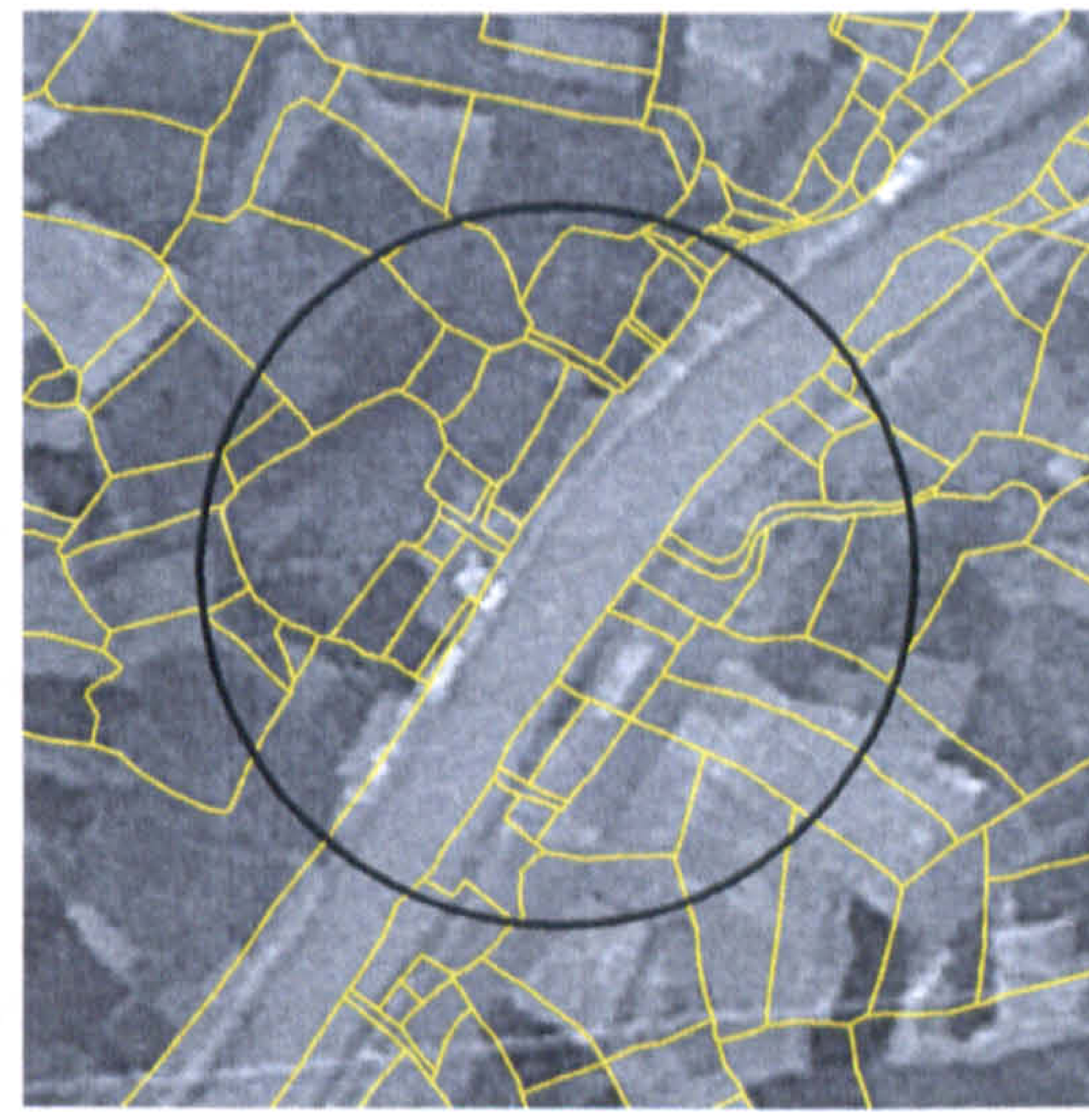


Figure 6-10: River Location, plots are small very close to river. (note: some distortion happened may be due to geocorrection)

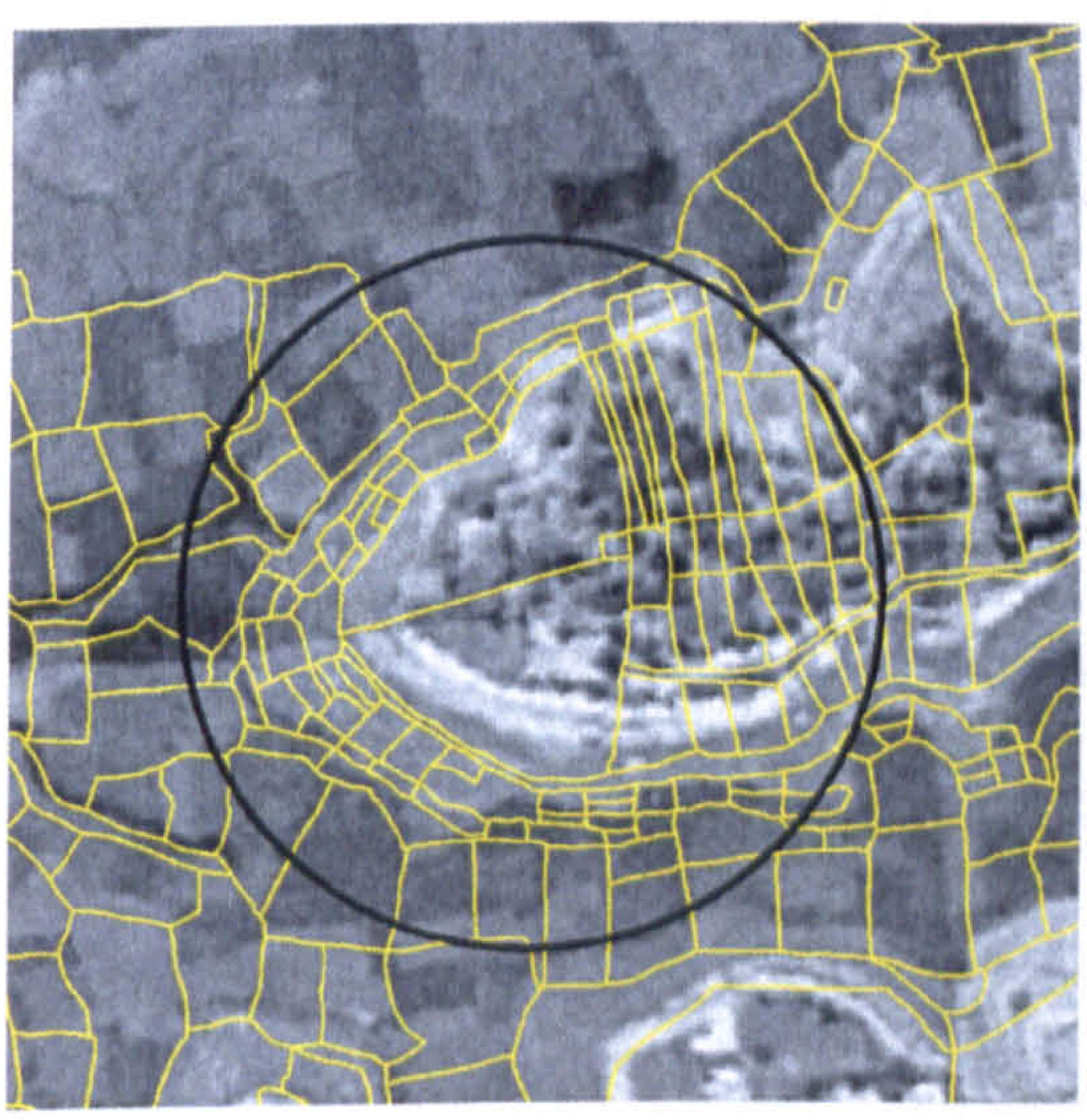


Figure 6-11: *Thhuta* (*chala* head) land located with small fragmentation on the slope (dhal).

Figure 6-12: Isolated *Dia* (semi-detached islet highland, isolated in the rainy season and attached with chala land in the dry period)

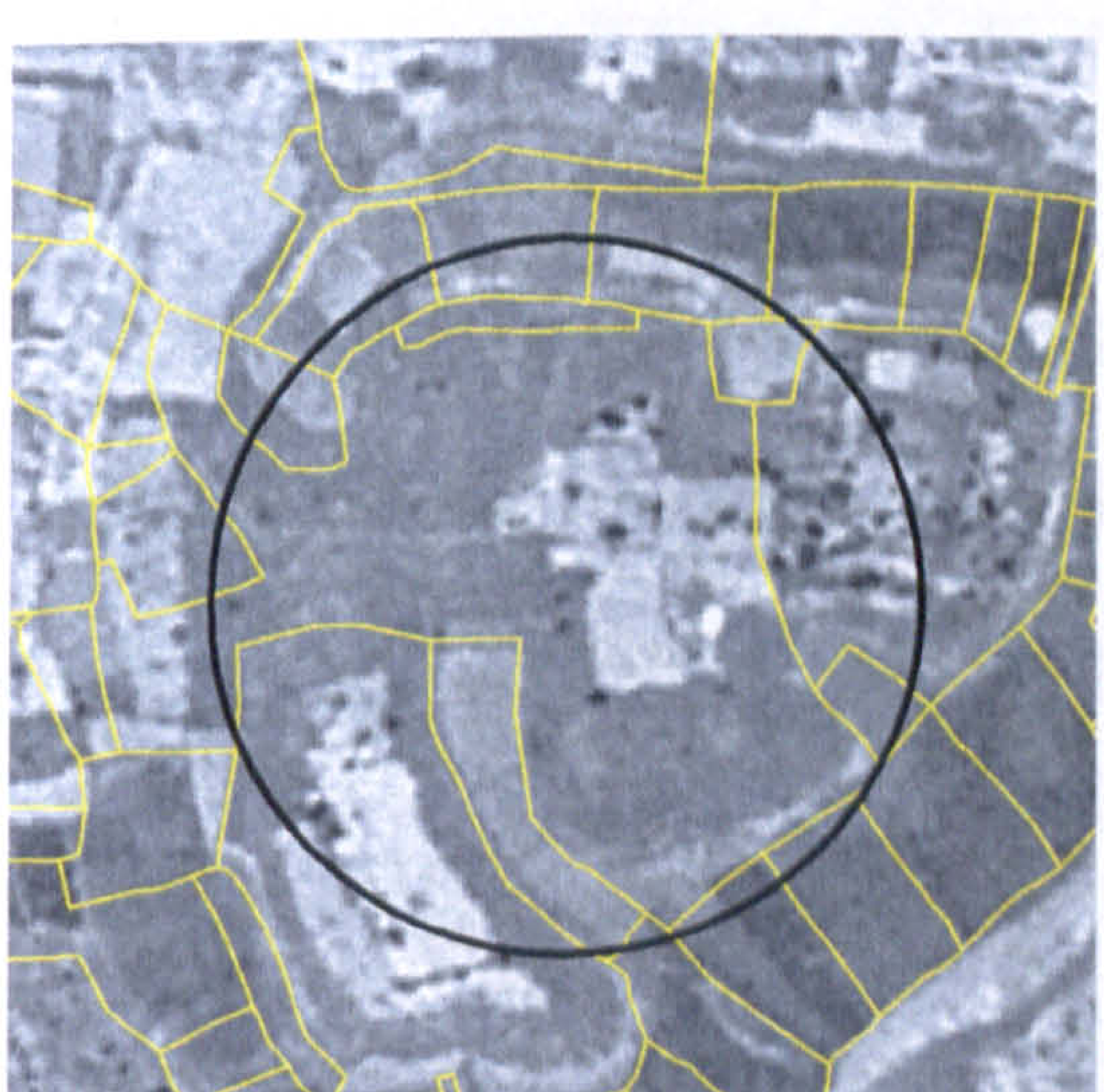


Figure 6-13: Grazing land for cattle

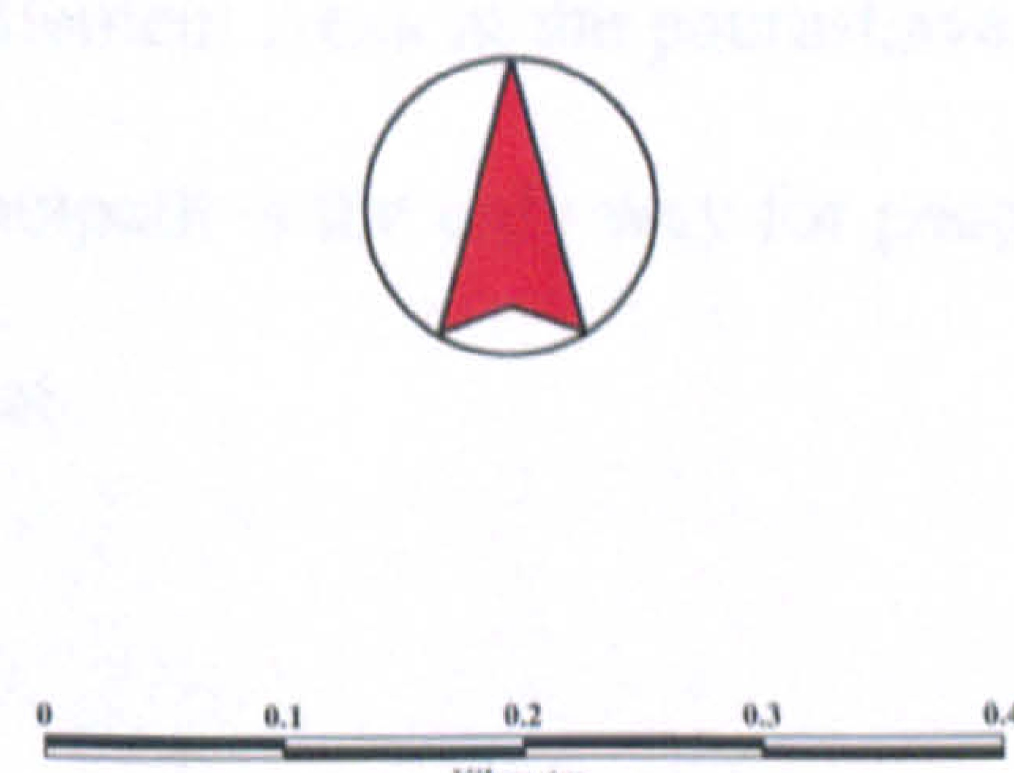


Figure 6-14: Scale and north line

(c) Mauza Plot Boundaries Visible on the Land

We have seen the *eyeels* (plot boundaries) on the map. How do they look in the field? There are several types of plot boundaries regarding development phases, as follows: As shown in Figure 6-15, on the rural agricultural area, mud-made land boundaries are important. The above agricultural land shows the visible boundaries, locally known as *eyeel*, which are used as public footpaths, to protect irrigated water from leaking, and to make the extent of land ownership and the jurisdiction of daag numbers. This boundary is human-made but has a broad link with the local topography. These boundaries are visible in the high-resolution RS images.

Figure 6-16 shows land that was similar a few decades back (Figure 6-15). But after the taking of ownership of the land by urban people, they built boundary walls with bricks to prove their claim over the land. The land is a precious matter to them as they invested a lot of money. Moreover, they do not trust their unknown neighbours. As a result, these brick walls replace *eyeels*, showing that the village is moving towards urbanisation. The land remains mainly vacant at this stage.

Finally, the pro-urban phase photo (Figure 6-17) indicates, there is no longer a concept of *eyeel* and urban people started living here. *Eyeels* are replaced by higher brick-made walls. The houses are in the relatively developed parts of Savar upazila. The planned areas have easy access while the unplanned settlement areas in the paurashava are very difficult to access. Sometimes a very narrow footpath is the only way for people to get access to their own property from the main street.

Figure 6-15: *Eyeels* (one kind of plot jurisdictive demarcation) of pre-development Phase

Figure 6-16: *Eyeels* of developing Phase

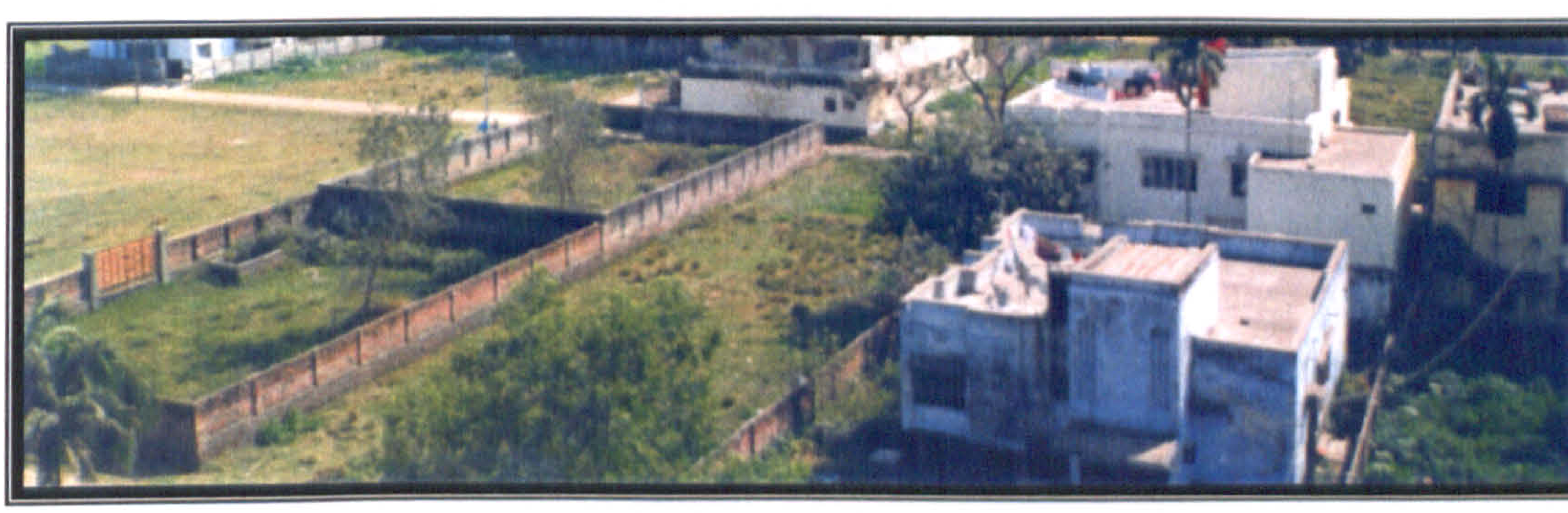


Figure 6-17: Eyeels of pro-urban Phase

(d) Bara Oalia Mauza: An Ideal Case Study

Bara Oalia is one of the most representable mauzas in Savar upazila (Table 6-4), showing the impact of Government institutions in the region, particularly the establishment of Jahangirnagar University in the 1970s. Moreover, it reflects most of the land types, land use and land cover available in Savar upazila and the surrounding region. The village used to have a very isolated village status with a dependence upon its forestry resource and a lack of infrastructure in and around the mauza until the late 1950s. Now it belongs to the shadow of a very rapidly expanding university and there have been other developments. As a result, the land use and land cover patterns are being significantly changed along with the land value pattern. It should be mentioned here that the mauza is still considered as a rural area, rather than an urban or peri-urban area but the influence of the university is rapidly changing with its land use pattern and population density. The university campus stands between the mauza and the national highway of Bangladesh named the Dhaka-Aricha highway.

***Daags* of Mauza as foundation for GIS attributes:** All the mauzas in Bangladesh have a unique number recorded in the Jurisdiction List (J.L.). The J.L. number of Bara Oalia Mauza is 589. Bara Oalia mauza's first cadastral and settlement survey was conducted in Dhaka District between 1910-17 at the plot level at a scale of 1:3,960 and Savar, in particular, was surveyed in 1915. This map was known as the Cadastral Survey (C.S. Map) and was used to collect revenue in a more efficient way than by the then Jamindars (landlords). This mauza map was divided into plots according to the local physiography and ownership. Each plot is locally known as Sabek Daag. For example in Bara Oalia mauza, each daag is uniquely marked by a numeric value from 1 to 1288. Later, as I mentioned before, after the independence of Pakistan in 1947, the new government abolished the Jamindar rule (Jamindar-Protha) under the East Bengal State Acquisition (SA) and Tenancy Act (1951) and the land was handed over to the local people. The area was then surveyed again in order to record the revised land ownership pattern in the new political arena, in what came to be known as the revenue survey (RS). The number of plots in this mauza increased from 1288 to 1547 during the period 1910s-1950s. In Savar, the mauza survey was mostly conducted in the late 1960s and implemented in 1975. The foundation of the present study is based on the *Haal Daag* (R.S. IDs), which have been constant since 1951. All field attributes (e.g. land values in taka), databases (e.g. plot area in size using GIS), and the relevant information (e.g. land types and their local names) have been collected, surveyed and mapped with the help of these unique *haal daag*, and all GIS, statistical and graphical data have been captured and recorded using this mauza map divided at plot level, and remote sensing images were integrated as well in order to achieve appropriate digital image processing and geo-corrections and calibrations. In the mid-1990s the Bangladesh Government carried out a new plot level survey to update the ownerships, but for various reasons, including administrative corruption and quality of data, this has still not been implemented. This latest effort is known as the Bangladesh Survey (BS). In the case of the Population Census, all mauzas are geocoded. The geocode of the mauza of Savar Upazila is 103, followed by a union code # 72 for Pathalia union.

Figure 6-18 shows the plot boundaries for Oalia Mauza with reference to the village boundaries and its surrounding mauzas with its plot boundaries. Regarding the aerial photos taken in 1990, the darkest colour (mainly in the middle i.e. Dakhin Oalia, Uttar Oalia and eastern Pandua) shows homestead vegetation and buildings. The medium light grey (mainly in the east i.e. Kasipur, Boaliapara and west Gakulnagar) represents seasonal crops, whereas medium deep grey (mainly in the west i.e. Jahangirnagar University and Islamnagar) is the chala land. The almost white colour (mainly in southern parts of Ammbagan, Pandua and eastern Kalunagar) indicates perennial water bodies such as beels and khals. A north-south linear feature in the east (outside Bara Oalia Mauza) is one of the most important national highways (Dhaka-Aricha) in Bangladesh. In the 1960s, it was introduced as a single lane-unmetalled (*katcha*) local road, and during the 1970s the road was rebuilt as metalled (*pucca*) road. In the 1980s it was upgraded to a double-lane regional road and finally since 2000, it has been reconstructed as a four-lane national highway. Due to the impact of the university, Amm bagan and Islamnagar have emerged since 1980s and 1990s respectively as new villages.

Table 6-4: Statistical Summary for the Bara Oalia Mauza

Parameters	Data and Information		
Graticules	90.244006° E 90.273041° E 23.879119° N 23.899184° N		
LCC Grids in metres (m)	2,768,018m E to 2,770,974m E 679,849m N to 681,856m N		
Total Number of S.A /R.S Plots (State Acquisition/Revenue Survey)	1,547 (Known as *Haal Daag*)		
Total Number of C.S. Plots (Cadastral Survey)			
Total Area	3,737,846 metre^2 or 3.737 km^2 or 92,212.16 Decimal or 922.12 Acres		
Average plot size	2,416 square metre (59.61 Decimal)		
Adjacent Mauzas (clockwise direction)	Senoalia (North); Uttar Crock and Dakkhin Crock (East); Gerua, Sundrip, Pashchim Sadhapur, Mohanpur (South); Dakkhin Sinduria, Beelbaril and Charigaon (West).		
Villages of Bara Oalia Mauza (including area covered in percentage)	Amm Bagan (11%), Boalia Para (9%), Dakhin Oalia (13%), Gokulnagar (17%), Islam Nagar (14%),	Kasipur (5%), Pandua (12%), University (12%), and Uttar Oalia (7%)	
Total Population Data Based on Census Surveys (Excluding Jahangirnagar University Part)	1951=1,130, 1961=1,692, 1974=2076 (field-based)	1981=2,572, 1991=4,443, and 2001=6,553	
Land Types (including area covered in percentage)	Highland with 1951 Shaal Baan (26%) Highland without 1951 Shaal (22%) Medium highland (7%) Medium lowland (18%) Lowland (23%) Very lowland (4%)		
Total land values of Bara Oalia *Mauza* in Bangladeshi Currency *i.e.* in Taka (2002 exchange rate was Tk 90 per £1) and also shown the mauza's Land Price Index (base year 1951 = 1)	1951 1961 1974 1981 1991 2001	**267,422 Tk.** **664,495 Tk.** **4,344,974 Tk.** **15,220,830 Tk.** **711,207,007 Tk.** **3,369,674,485 Tk.**	1 Tk = **1 Tk** 1 Tk = **2½ Tk** 1 Tk = **16 Tk** 1 Tk = **57 Tk** 1 Tk = **2,660 Tk** 1 Tk = **12,601 Tk**

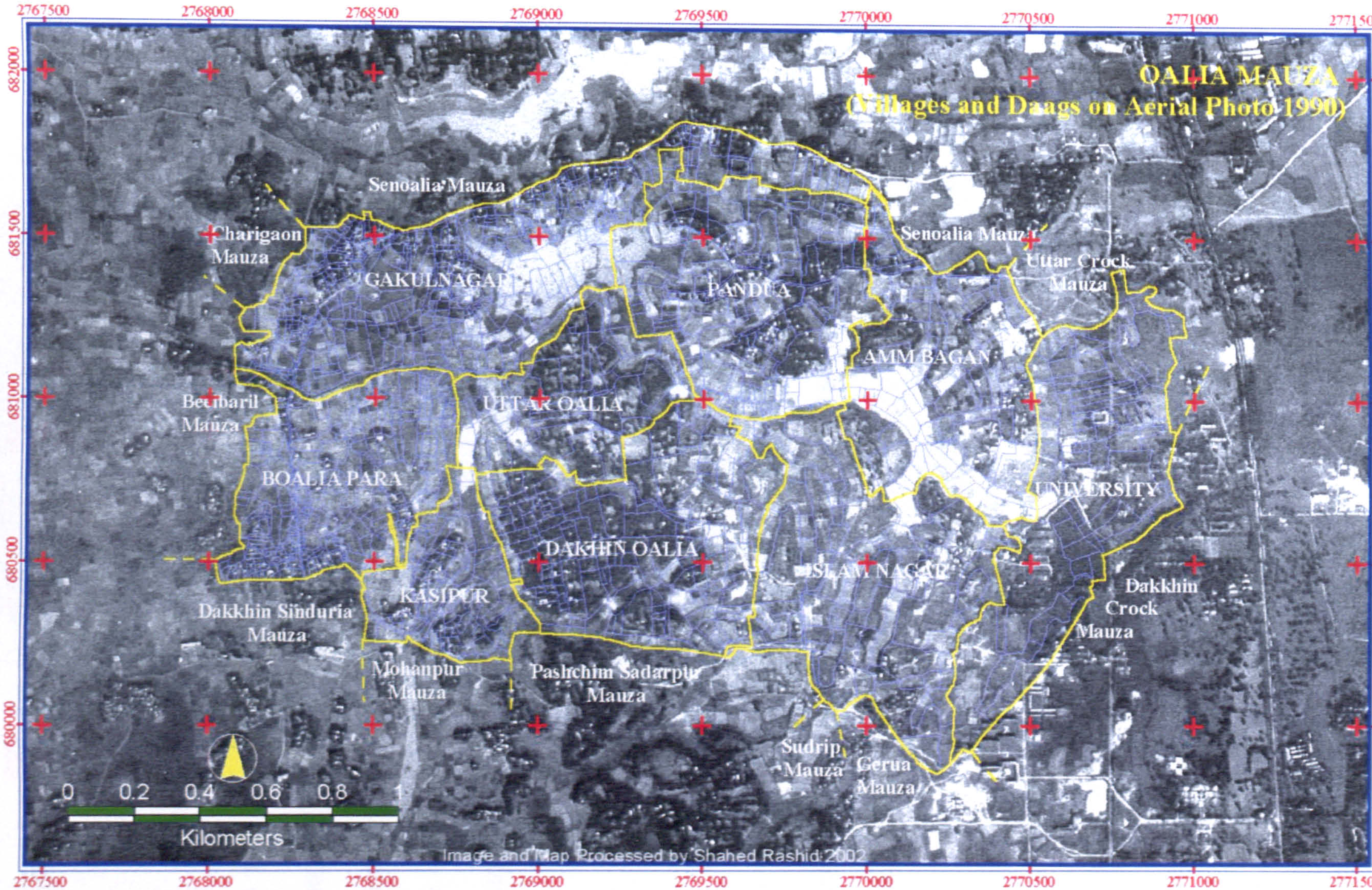
6.4.0. 'Stepwise Participatory Remote Sensing' for Land Use Mapping

This is one of the most valuable contributions of this chapter, where the key informants gave the details of their villages and helped me to understand the land transformation at plot level by giving the insights into the meaning of the high resolution satellite images and their interpretation. Based on their basic land use information, I later surveyed the necessary information for the other purposes of research, for example land value data from 1951 to 2001. I can describe this section as "Stepwise Participatory Remote Sensing" due to help given by informants involved with the Amin (well-educated skilled plot surveyors through a government or private level short training) and *Jomir-Daalal* (semi-educated or illiterate land brokers and work for rich people to buy and sell land suitable for their budget and location they choose). These informants were mainly over 50 years of age and therefore had a depth of knowledge about their lands and could remember the sequences of change over time. My prime focus was to show them the CORONA image of 1972 for discussion of the land plot features at that time with and without overlapped plot boundaries. In the last part of this section, I will give an example from CORONA images about the performance of identifying land features of Bara Oalia Mauza with and without the remotely sensed imagery.

6.4.1. Stepwise Features Identification

I wanted to understand the meaning of panchromatic high-resolution remote sensing images with overlapped Mauza Plot boundaries in order to map the past. The persons selected in this category (Table 6-5) are mainly those who have detailed knowledge of mauza maps of their villages. It was a unique opportunity to understand their views through the following stages.

(1) Identifying key landmarks available on the land;
(2) Identifying village and para boundaries;
(3) Identifying plots on the CORONA image;
(4) Recalling memories of the past;
(5) Reconstructing broad past land use and identifying prominent land types, land features and demarking roads;
(6) Understand and see the entire village and its sequence.



Source: Fieldwork, 2001 and Integrated *Aerial Photos, 1990*

Figure 6-18: Bara Oalia Mauza on a 1990 aerial photo showing its villages and environs. The villagers helped to draw village boundaries from a CORONA image.

Table 6-5: List of key informants for interviewing participatory CORONA Mapping

Key Plot Identification Informants	Occupations
Abdul Quadir Miah	Head Master and Amin, Bara Kakur
Nihar Ballov Naha	School Teacher and Hindu Leader with good knowledge of local plots, Bara Kakur
Ziarat Ali	Village Matabbar and Jomir Dalal, Ganda
Md Sohrab Hossain	Jomir Dalal and Business, Ganda
Md Fazlur Rahman	Primary teacher and Amin, Banshbari
Abdul Mannan	Head Master of Primary School and Amin, Banshbari
Sheikh Abdul Wahab	Local Amin and JU Staff, Bara Oalia
Md Abdul Latif	UP Member and Amin, Bara Oalia

The above mentioned people were highly valuable in identifying the correct plots, the key landmarks and the other associated phenomena. The process of understanding was:

(a) Feature Identification through Mauza Plots

In this case, they only found the plots where they were involved personally or their close relatives and neighbours resided. The success rate mainly depended on their own experience and number of plots they had surveyed in their neighbourhood. In total that is about 24 percent of the land. They also were able to identify some of the key landmarks of the mauza in finding plots well known to themselves.

(b) Feature Identification through CORONA Only

Here they were able to find out the key features easily, for example roads (mauza maps do not have road layouts), pukurs, bydes, chalas, orchards and so on. In most cases they could not tell me the plot numbers or the location of the houses except for their own or those of their relatives. Again, they could see the prominent features very easily of their own villages. Overall they identified 22 percent of the land, which may or may not overlap with the 24 percent from the mauza plots.

(c) Feature Identification through Plotted CORONA

In this case, I overlayed mauza plot boundaries on CORONA imagery and termed the printed output as 'Plotted CORONA' photography. I found a dramatic improvement of feature identification. They identified the remaining (half) plots very clearly. That means that if I had not provided the above two set of tests data separately, they could have identified almost all of the plots with only a 6-7 percent error. This takes relatively little time and can yield detail of the village as if all of the data is readily available. I prepared the most important land use maps of Bara Oalia Mauza (Figures 6-22 and 6-23) cited in the later sections with this technique and verified then later by using a plot to plot survey method and information from the field questionnaire placed in Table 6-3. It is interesting to know how this method works:

(1) **Mauza Plots:** They could see the plot boundary and the plot numbers clearly, and their positions in respect to other contexts of each plot have been distinguished. For example, if they see the plot number 1021, they also could see a tree in the corner of a plot. So they did not just see familiar plots, they could also triangulate through the visible evidence on the plot.

(2) **Visual Aid:** In seeing the picture of land features and the key land marks, they easily visualised their village and matched their in-depth knowledge about their land immediately. For instance, they could see the roads, nodes and the plots occupying and surrounding these roads.

(3) **Increased Confidence:** Matching mauza map and image for the same location made their arguments unmistakeable, much stronger with a greater confidence.

(4) **Forgotten Features:** They were able tell the story of the past, as the CORONA image was taken in the 1972 and almost the same time as the mauza maps were surveyed and implemented. For example, a pukur was there in 1970s, but now it has disappeared, so they could recall its history immediately. One of them told me, I had a palm tree and I sold it a decade back. That is why it is not now on the ground, but I had forgotten it.

(5) **Modified Features:** The most appealing thing is, that in villages I did not study in detail, with the reference of the integrated recent high resolution satellite images, it would be very easy to map and identify historical features plot by plot without any difficulty. For example, current lakes of the university were agricultural land in the past and reconstructing that land is possible.

(6) **Memory Recall:** When I talked about the pre-university situation at Bara Oalia Mauza, they gave me a rough idea of the past. But they failed to remember that there were a small village in the current location. When I showed them the images of the past, they immediately told me that they had completely forgotten about that.

(7) **Size and Shape:** One key informant told me that he guessed the size of the Oalia beel before, but had no idea how it would look on the mauza map. Now he could easily find out the exact plots from the mauza map and know their shapes correctly.

(8) **Village Boundary:** For the first time, my key informants drew the village boundary line (Villages boundaries shown in Figure 6-18 are based on this information). They knew the name of villages in the mauza but had no idea about their extent on the map. But from the image, they could see the eyeels dividing the villages they knew on the ground and drew a line using them. In Bangladesh, there is no official record of village boundaries but through participatory remote sensing methods it would be very easy to establish the boundary lines of each village in any mauza.

(9) **Land Reform:** I was told that during the last survey, the field surveyors took money to register the land types and uses, on the basis if that the tax of land was being fixed. The villagers gave money in the hope that their land would be taxed low. But if the government use image interpretation techniques, it would be easier for them to find out the land types of the each plot.

(10) **Development Programme:** There are several programmes to construct (katcha) roads under the aid programme of 'Food for Work', but the layout for the roads is never discussed with the local people. In my view the planning would be improved through opinions contributed by the villagers.

(11) **Crop Calendar:** The informants helped me to draw up a crop calendar of the mauza with the details of the various crops (Tables 6-7 and 6-17 are based on their primary guidelines) and the detail map of land types. They easily understand the land types and land use with their distribution. But from only the mauza map, they could not do it. We could also draw the extent of orchards with their help. It is quite fascinating. Our database of mauza and understanding of CORONA have been very well developed with their support.

(12) **Reference Plots:** They can name the owners of a remarkable number of plots and these can be used as reference points to find other plots. For example, an informant identified one plot as owned by 'Jamal Member', and then we asked the ordinary villagers, 'can you show me the house of Jamal Member?' Later, we used that house as base point for further information on neighbouring plots.

(13) **Disputed Plots:** The key informants are very well informed about disputed plots, recently sold plots and plots of prominent figures in the community. All this experience they gained by dealing with mauza maps although they not familiar with natural features. With the help of the CORONA image, they interpreted the physical features very easily and marked the plots for me on the mauza maps.

(14) **Government Land:** They could not mark the prominent buildings of Jahangirnagar University on the mauza, as they were not used to dealing with government property. When they saw the layout of roads of the university on the CORONA Image, they managed to mark the buildings and identify the boundary of the University with their villages.

(15) Extent of Mauza: I found that if I did not mark the mauza boundary on the CORONA Image, the key informants found it difficult to map it themselves.

6.4.2. Explaining an Example: Performance on Plotted CORONA

Figures 6-19 and 6-20 illustrate very important findings regarding the performance of the participatory CORONA Mapping with the help of mauza plot boundary in Bara Oalia Mauza. From the map and Table 6-6 we can see the spatial distribution of the mapping ability of the key informants. There are four steps shown on the map:

1. **With Mauza Map (Step 1):** When we provided only mauza maps to the key informants, they successfully identified 186 plots (out of 1547 plots). These were mainly in the areas where they resided and those now under development or rapid change and the land prices are relatively high, particularly on or close to chala lands. They are involved with these areas land more than other plots. They were able to give the details of 24 percent of plots in the mauza. The average sizes of these plots were 118 decimal.
2. **Using CORONA Only (Step 2):** When I showed them the CORONA image, the performance of the informants was much more concentrated on the major physical boundaries and the areas where plots are clearly visible from space and can be distinguished easily. Here they marked a total of 342 plots, which cover about 21 percent of the mauza. The average size of these plots was 60 Decimal, mostly agricultural land, which explains why they are fragmented and relatively small.
3. **Both CORONA and Mauza (Step 3):** In this case, I used CORONA images marked clearly with mauza plot boundaries. This time the panel identified about half (49 percent) of the total plots of Bara Oalia. They recognised 637 plots of the mauza with an average size of 70 decimal. So with CORONA (with and without mauza overlapping) they were able to find about 71 (22+49) percent of the land and if we include the 'mauza only' step, then the success rate is 93 percent. This was beyond my expectation. For the first time, they drew the boundaries of all 9 villages perfectly. They identified the plots just in a session of half a day. It would take weeks for an expert team of surveyors to do the same job.

4. **With Field Verification (Step 4):** After the participatory approach, I went with a group of trained field-assistances to verify the field boundaries. We got only a total 7 percent error, which was mainly related to small sized plots, i.e. average of 17 decimal, that were problematic to identify due to the small size of plots and used mainly for houses. Here 382 plots were identified wrongly or could not be recognised at all. So with the participatory approach we got a total 93 percent accuracy.

Table 6-6: Performances of the Key Informants at Various Stages

Steps	Participatory Approaches With Key Informants	No of Plots	Decimal of Land	Average Plot Size	Percent of Land	Cumulative Performance
1st	With Mauza Map	186	21920.52	117.85	23.77	23.77
2nd	Using CORONA Only	342	18981.16	55.50	20.58	44.36
3rd	Both CORONA & Mauza	637	44867.29	70.44	48.66	93.01
4th	With Field Verification	382	6443.19	16.87	6.99	100.00
	Total (*Average)	**1547**	**92212.16**	**59.60***	**100.00**	

I used the key informants (Figure 6-21) in several ways:

1. To understand their skill of recognising plots regarding mauza maps;
2. To identify the expected plot from the images;
3. To get the history of any plot and village; and
4. To see their performance in identifying any specific land features and broad land uses.

With the help of one or two *amin* or *jomir daalal,* it is possible to draw thematic maps on cultural, environmental, and demographic data. Also, a rich GIS database has been generated based on Plot_IDs (e.g. some attributes of Table 6-2). The land value map is a classical example of information gathered (Figure 6-38). The following sectors can benefit from findings such as these:

1. Local Government Engineering Dept;
2. Land records and surveying;
3. Land reform, planning and taxation;
4. Database development of the owners of land;
5. Monitoring urban expansion and development;

6. Mapping river bank erosion and course shifting;
7. Disaster management and relief;
8. Mapping the impact of any land acquisition and land values;
9. Identifying the plots affected every year by flooding and their extent of damage;
10. Monitoring agricultural activities;
11. Bangladesh Space Research and Remote Sensing Organisation;
12. Local Union and Upazila Parishads (Councils);
13. Rajuk's detail area plan and its monitoring; and
14. Understanding the pattern of land use change and its process of transformation.

However, villagers were very surprised seeing the CORONA images alongside their familiar mauza maps. They frequently asked how we got these maps, how it is possible to get such an image dating back to 1972; how the Americans can see our land, and do they know everything about us (as I told them that the image is from American Spy Satellites, named the CORONA programme). They also wanted to know how they could get a copy; how this will help me in my research; how villagers can benefit from my research; why I am particularly interested in their village; how did I match satellite image and mauza map (they thought that America also has mauza maps of their village and that the map I took to them had been printed by the US with plot boundaries); do I have any other motive than research, and so on. Initially they accepted me with some doubts but later they had a high confidence about my good motives regarding their villages.

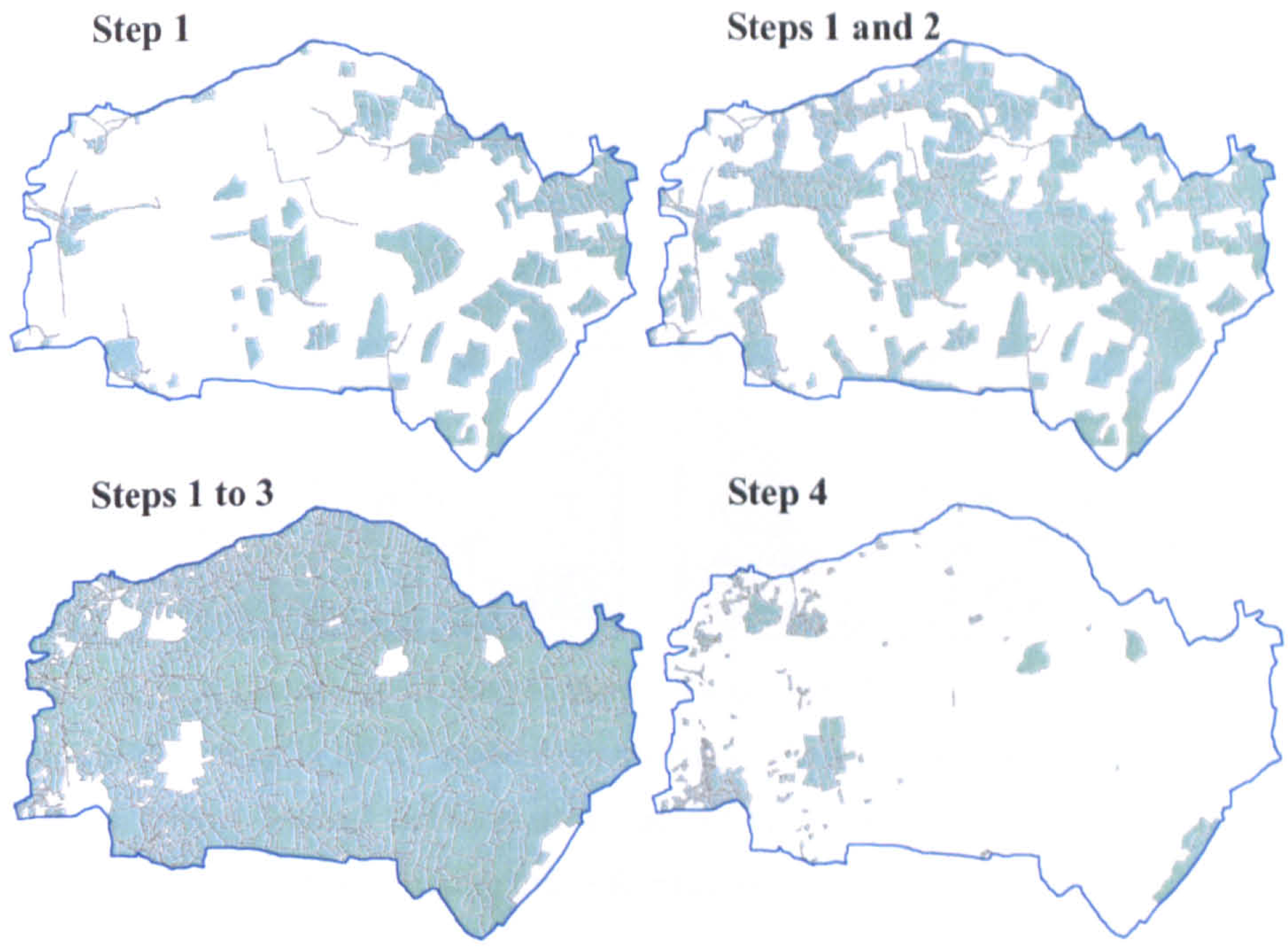


Figure 6-19: Cumulative Stepwise Performance of Key Informants- 'Step 1' shows the performance using Mauza map only; 'Steps 1 and 2' map shows the combined performance of Mauza and CORONA separately and 'Steps 1 to 3' map shows the all cumulative total of Mauza only, CORONA only and Plotted CORONA; and Step 4 illustrates the error plots were found using plot to plot verifications.

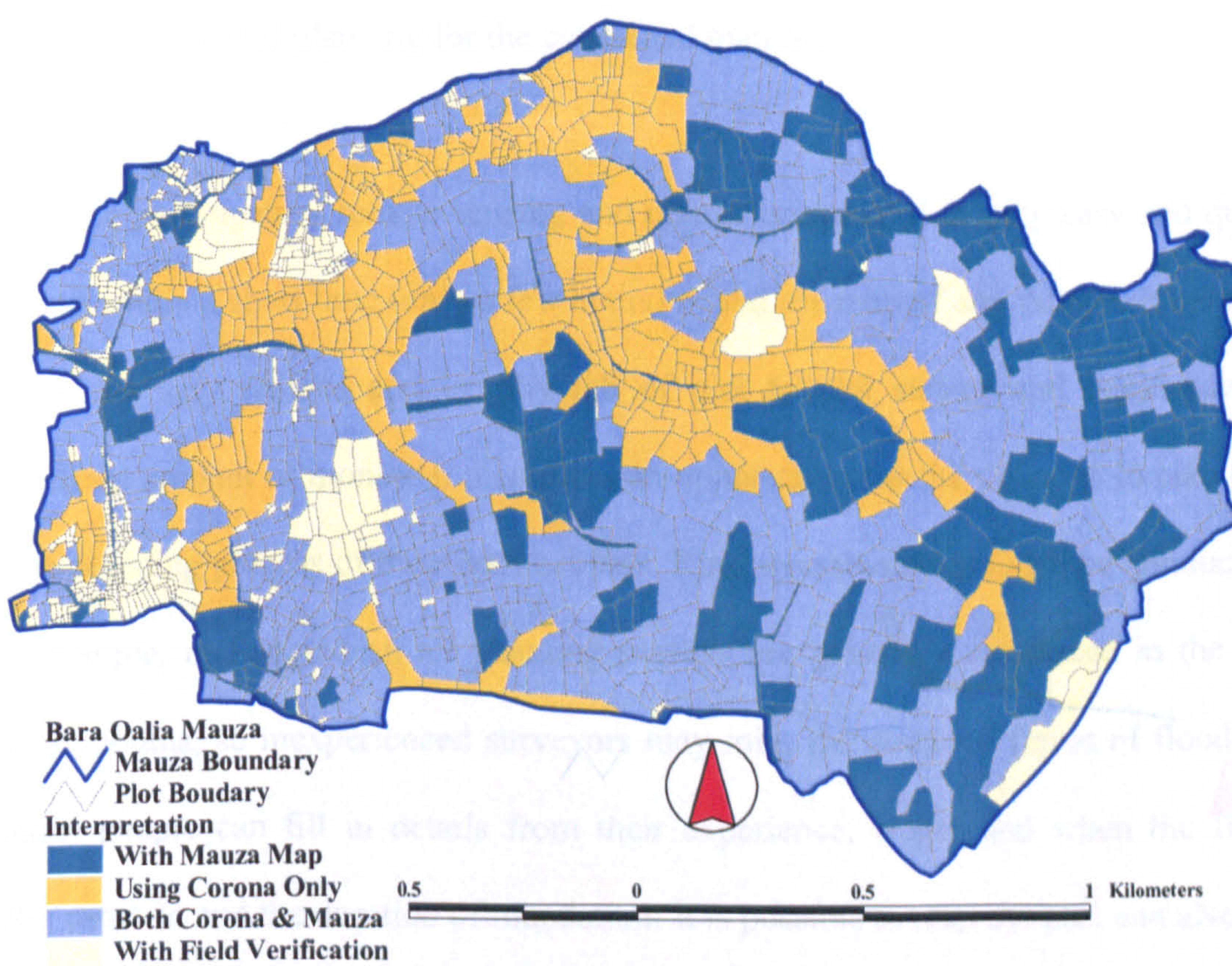


Figure 6-20: Performance at Individual Steps- The performance of key informants with and without CORONA. It is very interesting to see their exceptional performance in the participatory CORONA Mapping. The colours show the methods used by the villagers to recognise the plots and their further details.

Figure 6-21: (left) A discussion of the prominent local villagers, the key informant here was Md. Abdul Quadir Miah, sitting in the 2nd place from the right. The meeting was arranged in a Government Primary School. (right) Trained field-assistants are verifying the information provided by the key informants and surveying for any missing plot information.

The participatory imaging could also be used for participatory planning purposes at village level. It may not work for the upazila level, but may prove useful at the plot to plot level of detailed planning for the concerned mauzas.

Using the participatory remote sensing and mauza mapping, it is very easy and quick to draw within a short time (only a few hours) a land use map of any village. It helps to reduce the very tedious and lengthy job of plot to plot survey and could save a significant amount of money. It also gives an opportunity for the villagers to take part in the planning process of their own habitats. Risk assessments can also be conducted, for example, in Bangladesh all planning surveys are generally conducted in the dry winter months, so inexperienced surveyors may miss the potential threat of flooding. Village people can fill in details from their experience, where and when the flood water came-in and the duration of inundation. It is possible to map the past and also for planners to get valuable information on how their planning layouts are seen at government and private level, which has never been attempted before in Bangladesh.

We should engage the skill of the villagers, which has not been done before systematically.

6.5.0. 'General Land Use' for Spatio-temporal Pattern Analysis

Bara Oalia Mauza had a simple and a very traditional land use system in 1951, like other parts of Bangladesh, but gradually it became very complicated. By 2001, the land use pattern was completely changed and very remarkable change happened over time. Here we will take into account several basic issues briefly presented in Figures 6-22 and 6-23. These are:

(a) How many categories of land were available in 1951 and 2001;
(b) What was their total area and has it increased or decreased?
(c) Are there any new phenomena and what are the reasons for such new land features?
(d) Are there any land features which are completely missing? What are the reasons behind that? And in the later section we will see:
(e) Which land category has the most influence? How can we measure that?

A brief description of each land use category follows:

(a) Water Bodies (WB)

In 1951, there is no doubt, that the extent of perennial water bodies was much bigger, i.e.125 acres, but in 2001 it was only 45 acres, a two-thirds reduction of the permanent source of surface water (Figure 6-24). I asked the farmers why this had happened and they responded saying that the massive use of perennial surface water for the irrigation of higher land in the dry crop season has created this problem; two, there had been excessive use of ground water for drinking and irrigation for the *chala* lands, so the groundwater table is now deeper; third, the Bansi river does not carry the same flow of water in the dry season. There is also a problem of the reduction of permanent water bodies in the greater region, as we also saw from the satellite image and the width of

Bansi river has narrowed dramatically. There are three types of water bodies visible, there are: khal or canal, pukurs or lakes and perennial lakes or Beels. Khals are elongated narrow shapes and traditional *shnako* used to work in the past as a bridge (Figure 6-25) between *paras* instead of currently built modern bridges; pukurs are also square shaped and beels are huge and irregular shaped. Such natural features were the only source of fresh water in the predevelopment phase but now ground water is being used alternatively or in parallel. The lakes on the Jahangirnagar campus are based on the previous track of bydes, and this is a new phenomenon is this region. These lakes and pukurs are the main zones of modern fish culture. It is also to be remarked that with the reduction of permanent water bodies, a significant amount of land has been added for agriculture practices in the dry seasons, a total of 162 plots.

(b) Halot or Katcha Roads (RD)

Some plots are not owned by the local people, particularly those used by local villagers. In the C.S. 1915 survey local *katcha* roads were for walking or bullock karts. But later on, the land use pattern became complex and the provision of tracks was not enough for local demand to go from one *paara* (like a hamlet) to another. After massive population growth in the area, other plots, completely or partially, were dedicated to the road network, long linear plots 10-20 feet wide. The early society was dependent on this road layout, but now the situation is very complex and a significant number of un-recorded plots are taken in for the construction of katcha, semi-pucca or

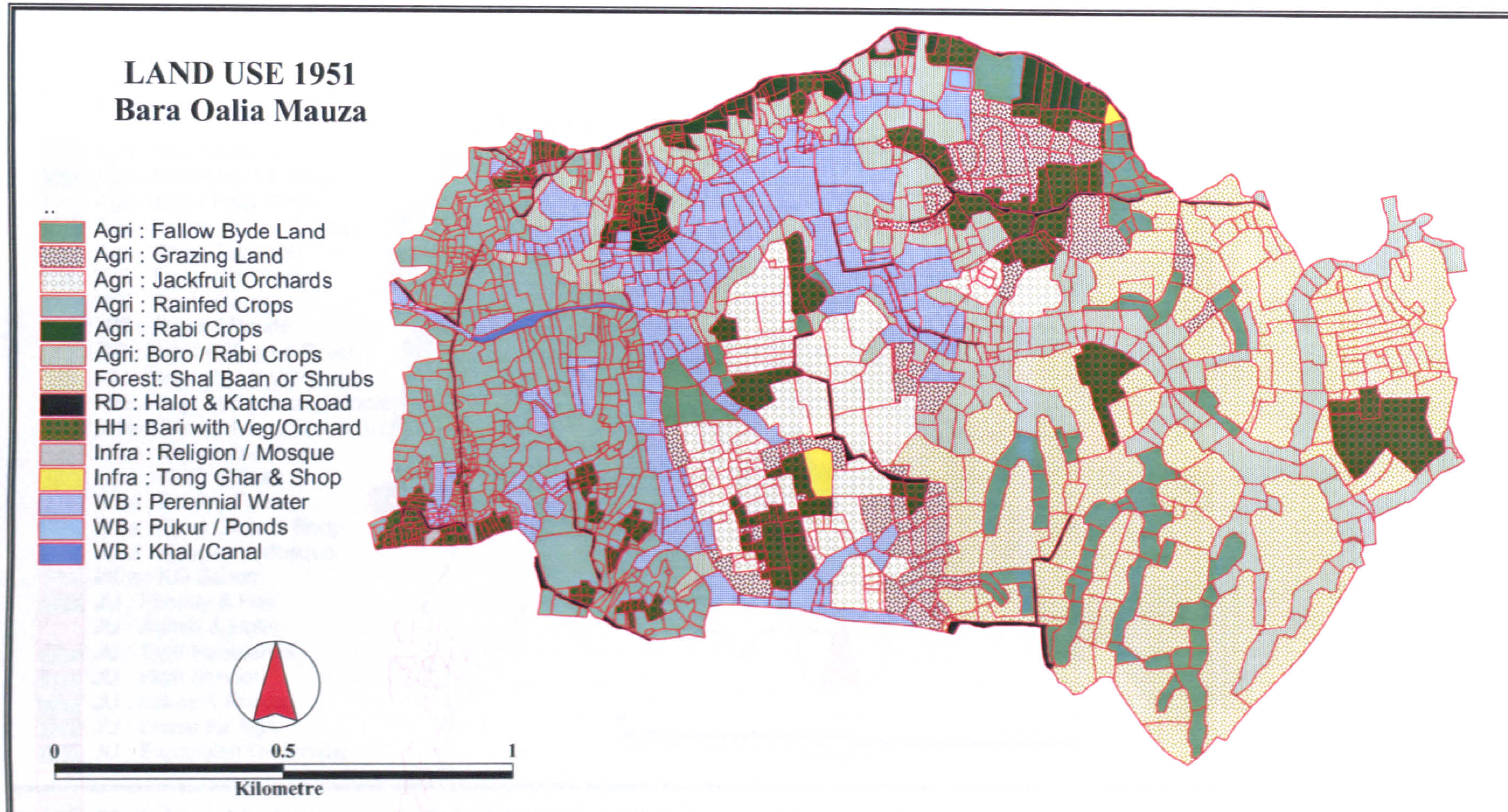


Figure 6-22: A traditional land use pattern of Bara Oalia mauza in 1951 is prepared based on RS image and plot to plot Field Survey methods. Here: Agri = Agriculture; HH = Households; WB = Water Bodies; RD = Katcha Road and Infra = Small Infrastructures.

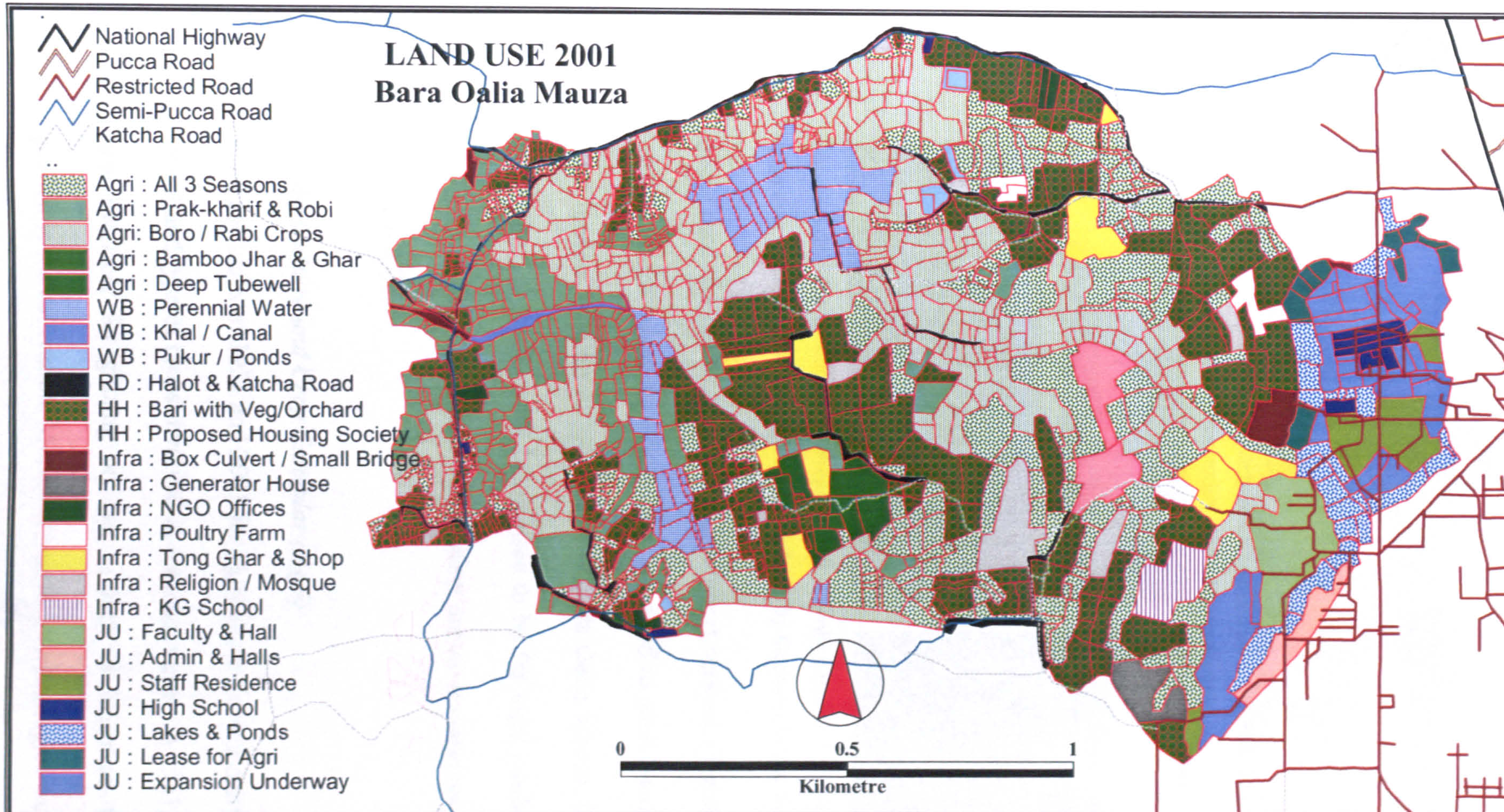


Figure 6-23: A detailed land use pattern of Bara Oalia mauza in 2001 is prepared based on RS image and using plot to plot Field Survey methods. Here: Agri = Agriculture; WB = Water Bodies; RD = Katcha Road; Infra = Small Infrastructures; and JU = Parts of Jahangirnagar University i.e. the mauza occupy only about 15 percent (104 acres) of the total JU area (705 acres).

Figure 6-24: The extent of water bodies gradually decreasing.

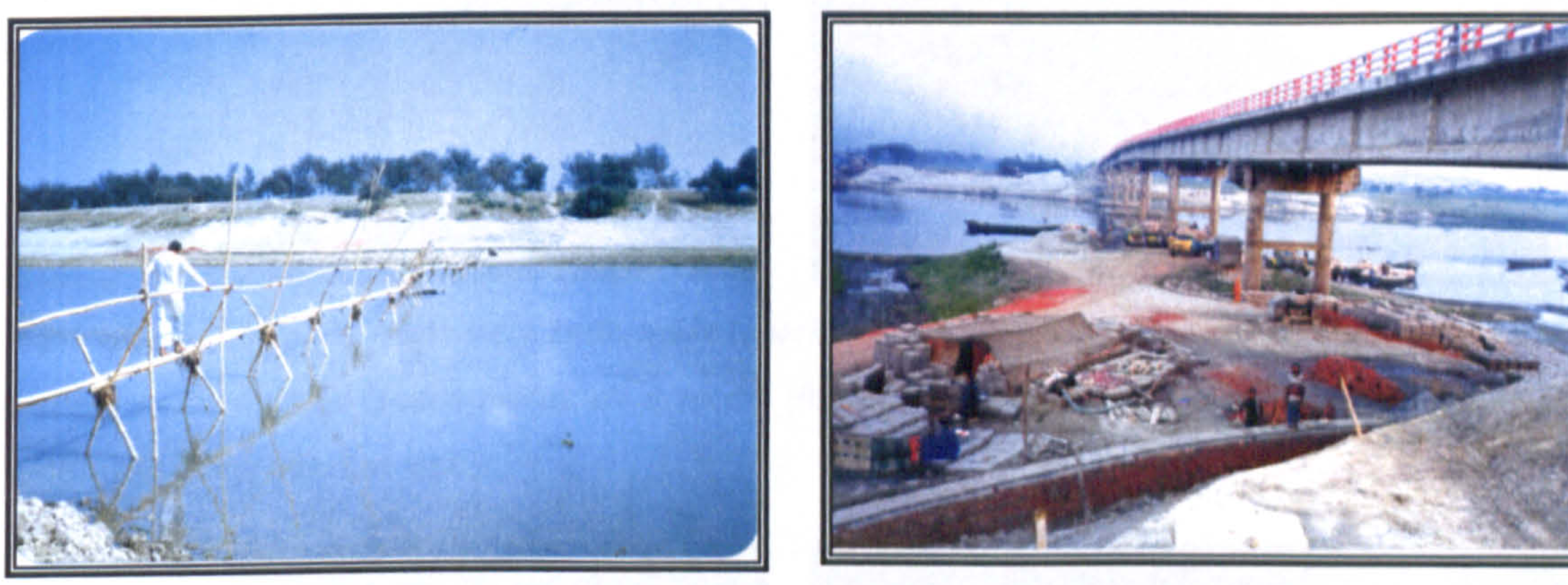


Figure 6-25: The traditional wobbling *shnako* (bamboo-made overpass or *katcha* bridge) in order to cross over the river, now these are mostly replaced by the *pucca* bridge i.e. RCC made.

pucca roads for the rural to national transport network (Figure 6-26). The northern and eastern katcha halots have now been upgraded to semi-pucca roads. If we look at the 2001 modern road layout of the east of Bara Oalia Mauza, there is no match with the 1951 situation at all. Some halots used to be for local *nauka* (a typical local boat) in wet seasons but due to later earth-filling are now commonly used for *rickshaw*-vans (Figure 6-27).

(c) Agriculture and Crop Calendar (Agri)

Land use maps of 1951 and 2001 for agriculture show a dramatic change in the spatial extent and type of crops involved in seasonal terms. In 1951, there was a lot of fallow land available for grazing or, due to lack of irrigation facilities, which was not profitable for cultivation. Moreover, modern technologies were not available for tilling purposes. It is also remarkable that designated grazing land was also visible for cattle, oxen, goats and lambs. Only one crop was cultivated in the fields, mainly rain-fed paddy, rabi or boro crops (for details, see Tables 6-7 and 6-17). Moreover, a significant number of jackfruit orchards were visible at that time. These were an alternative source of food during dry or drought periods for poor farmers.

Figure 6-26: The early roads were earth-made (*katcha rasta*), therefore only suitable in the dry seasons and the modern roads (*pucca rasta*) are a recent phenomenon popular but very crowded (passengers visible top of the buses as well).

Figure 6-27: In the predevelopment phase in the rural areas, rainy seasons were suitable for transportation and the traditional boats (*nauka*) played a role for carrying goods and people. Later rickshaw-vans took over gradually, because they are also suitable in dry seasons. Now modern-buses and lorries do the job as well.

During the field work, I noticed that there had been big changes in agricultural practices and in the crop calendar. These are due to the following reasons I gleaned from interviewing local farmers:

1. Traditional and primitive types of crop cultivation including the staple food rice until the 1950s.
2. The innovation of HYV crops in the early 1960s;

3. Improvement of irrigation facilities based on surface water and ground water in the 1960s and 1970s;
4. Land price increases in government-acquired sites due to the construction and expansion of the university campus;
5. Production cost of a crop versus its selling price in the nearby market;
6. Massive population growth;
7. Decrease of forested areas and orchards;
8. Seasonal variation of crops and increases of crop intensity over time;
9. A lot of local varieties have disappeared due to increases of production cost and non profitability as HYV crops;
10. The changing status of land types in the mauza, for instance, the low land was more expensive than the chala lands in the predevelopment stage, because the villagers were highly dependent on the agro-based economy. After starting the process of development, there were alternative opportunities created due to the increase of secondary and tertiary economic activities in the area;
11. Dramatic population increases also had an impact of agricultural activities and affected the overall crop calendar.

If we look at Table 6-7, the top row contains the name of crops; whether or not the particular land is suitable for certain crops and trees; land types available in Bara Oalia mauza, that is from highland to very lowland; the main cropping seasons in Bangladesh and their approximate lengths in months. Here March to May is a very dry (sometimes drought) season locally known as the Prak Kharif Period; the rainy season and floods occur between June to October, known as the Kharif cropping season. Finally, the winter is a relatively rain-free period. Moisture is still held in the soil from the immediate past rainy monsoon season. This season is also highly dependent on surface (FCDI, flood control drainage and irrigation) or groundwater irrigation systems. This period is known as the rabi season. Cropping practices in Savar are changing rapidly (Figure 6-28) due to modern cultivation methods; improved irrigation facilities; the introduction of HYV crops; conflicts in the urban-rural transition and impact on agriculture; the usage of chemical fertilisers for multiple crop cultivation on the same plot, generally 2-3 crops in a year. Some crops have either disappeared or are only occasionally cultivated in this region and others are in high demand. It is also remarkable that the farmers used to depend on the cow-ploughers but now a power tiller is more attractive in terms of labour cost, ploughing time and dry season cultivation (Figure 6-29). Nowadays, power tillers are the most important ploughing tools in Bara Oalia Mauza.


Figure 6-28: The left hand photo shows a traditional paddy field in a byde while right hand photo shows the new practice of potato cultivation on the chala lands using dry season deep tubewell irrigation and fertilizers.

There are two dimensions of the cropping pattern. One is the time dimension, and the second is land types. In the early stage, crop cultivation was not suitable on *chala* land, but, due to the recent availability of better irrigation and appropriate fertilisers, the upper land also now is used for cropping (Figure 6-28). For example, based on Table 6-7, I will describe the spatio-temporal situation of rice crops and their seasonal variability and similar explanations will be applicable for Table 6-17 given at the end of this chapter for other crops and for some prominent perennial (mainly fruits) trees.

Rice is the staple food in Bangladesh and is eaten at least twice a day. People are dependant on this food for survival, mostly in the rural areas, where people eat rice three times a day. In Bangladesh, three types of paddy are cultivated by local farmers. These are Boro Paddy, Aus Paddy, and Aman Paddy. Boro Paddy is mainly HYV and it grows in the Rabi season and so it is totally dependent of irrigation water. This is a new crop in Bangladesh and commenced from the 1960s. It cannot grow in stagnant flood or rain water, so it is restricted to the winter. High, medium high and medium lowland are suitable for Boro rice. In the 1960s, introduction of irrigation water, and the availability of limited amount of HYV Boro, made it possible in the western medium low and lowland (S) parts of the Bara Oalia Mauza to extend the area under boro rice cultivation, but is was not so frequent at that time as the farmers were still not confident about the quality, taste, market demand and consequence of the cultivation. It proved to be very successful and when the then Water Development Board provided ground water irrigation facilities in the region, it started on the medium higher bydes and on chala lands.

Figure 6-29: Still Farmers depend on the traditional use of cow-plougher (*langol*) but gradually power tillers are taking thier place for turning up the soil in ridges and furrows.

Lowland boro was not as profitable as expected (M) by the farmers and very lowland (locally known as *nul-jomi*) is not at suitable (U) at all as it is the zone of stagnant water. This boro gives a first glimpse of hope to the farmers, that relatively higher lands can also be a part of paddy cultivation. In Savar, local bydes are sometimes known as *boro-jomi* (*boro*-land). The land use map of Bara Oalia shows that the extent of perennial water bodies is decreasing and, therefore, the relatively low areas are also coming under *boro* farming. Bangladesh is almost self-sufficient in rice production due to the massive expansion of boro cultivation and improvement of irrigation systems (Figure 6-30). As a result, farmers can produce a maximum of three crops in plots per year and this has helped to increase the intensity of cropping. Boro cultivation is responsible for a serious loss of crop diversity in Bangladesh and also in the mauza where it has also reduced the fertility of land and been responsible for pollution by chemical fertilisers and insecticides.

Figure 6-30: The deep tubewell (left) has made the barren *chala* land (right) fertile and productive.

Regarding Aus Paddy, it is the crop of the Prak-kharif period in Bangladesh. In the early 1950s and 1960s, it was widely cultivated in the region and, at that time, was often the only type of crop available. It was a LIV (local improved variety) broadcast (locally known as *bona*) Aus, and it was not dependent on irrigation water. Due to its better eating taste and good smell, this paddy is occasionally cultivated still in some plots. Later transplanted (local name is *ropa*) rain-fed and irrigated varieties were developed but, due to its high yield rate, irrigated Aus is now more popularly cropped in the region. The farmers harvest the Aus crop before the arrival of the monsoon flood. Medium highland and highland are most suitable for the aus paddy.

Bangladesh is a very flood-prone country, but the level of flooding is not the same in all land types in Bangladesh and, so the variety of paddy cultivated in this time is fairly significant. Aman is the main crop in the monsoon, locally known as the kharif crop period. Aman paddy is also classified as either transplanted/ropa or Broadcast/bona aman. If we look at Table 6-7 most of the varieties are not popular currently although they were widely cropped in the past. The most popular is HYV rain-fed Aman as there is no scarcity of rain in this time. These crops are also cultivated in the higher lands with only the exception of the local deep water aman paddy, but it is not available now as the yielding capacity is very low in comparison to HYVs.

The HYV boro paddy yields generally 3.21 tonne/hectare for HYV but in the case of LIV, its capacity is only 1.53 tonne/hectare. The production of Aus paddy is 1.84 tonne/hectare for HYV and 0.62 tonne/hectare for local varieties. Ropa paddy has a slightly higher yield in comparison with bona varieties in all cases. Aman locally has 1.33 production capacity while HIV has 2.43 tonne/hectare. Based on this information, it is easily possible to calculate the total production of rice and its spatial distribution on the map. Due to the shortage of space, I will not develop this topic in further detail here in this chapter, but as we have detailed field level data for various crops of the region, GIS can develop the necessary maps for decision-makers concerned with agricultural planning in Bangladesh.

Figure 6-31: The lowland (*naama* or *chwak*) traditional irrigation with the done-kanda (left) and high land (*taan* or *chala*) modern irrigation though canal using deep tubewell (right). The basic difference between them is the absence or presence of perennial trees.

It has to be acknowledged that Oalia mauza has exceptionally diversified cropping land but this advantage is being gradually overpowered by the other economic activities of this region. Behind this diversification, *done-kanda* and *khamas* (peddle based traditional irrigation tools) were mainly responsible for low land irrigation and production of crops and for the highlands deep tubewells and their canal (1 metre wide) networks help to improve production of rice and rabi crops (Figure 6-31). At the end of this chapter (Table 6-17), most of transformation history of the individual crops is given based on interviewing farmers during fieldwork.

Table 6-7: Generalised transformation of paddy cultivation of Oalia Mauza by land type and seasonal crop calendar at decennial scale over the last 50 years.

RICE* CULTIVATION		Suitability by Land Types	LAND TYPES					SEASONS			DECADAL SHIFT					
			Highland	Medium Highland	Medium Lowland	Low land	Very Lowland	Prak-Kharif (Mar-May)	Kharif (June-October)	Rabi (November- Feb)	Early 1950s	Early 1960s	Early 1970s	Early 1980s	Early 1990s	Early 2000s
Boro Paddy *(Boro Dhaan)*	HYV Irrigated	S	X	X	X						N	O	O	F	F	F
		M				X									O	F
		U					X									
AUS Paddy *(Ropa/ Transplanted Aus* and *Bona/ Broadcast Aus*)	Transplanted Aus HYV (Rain-fed)	S	X	X							N	N	F	F	O	N
		M														
		U			X	X	X									
	Transplanted Aus HYV (Irrigated)	S	X	X							N	N	F	F	F	O
		M														
		U			X	X	X									
	Broadcast Aus Local (LIV)	S	X	X							F	F	F	O	O	N
		M			X						N	F	O	O	O	O
		U				X	X									
Aman Paddy *(Transplanted Aman* Or *Ropa Aman)*	HYV Irrigated	S	X	X							N	N	O	O	O	N
		M														
		U			X	X	X									
	HYV Rain-fed	S	X	X							N	O	F	F	F	O
		M														
		U			X	X	X									
	Local	S	X	X							F	F	F	O	N	N
		M			X						F	F	F	O	O	O
		U				X	X									
Broadcast *Aman* or B. *Aman (Bona Aman)*		S		X	X						F	F	F	F	O	O
		M				X					O	F	F	O	N	N
		U	X				X									
Local Deep-Water Rice Broadcast *Aman (Goveer Panir Bona Aman)*		S				X	X				F	F	F	O	O	N
		M			X						F	O	N	N	N	N
		U	X	X												

***Note:** other crops and fruits cultivation calendars have been placed at the end of this chapter.

Data Source: Fieldwork 2001

INDEX to Tables 6-7 and 6-17 (end of the chapter):

S= Crop/ vegetation/fruit cultivation/ production/ input cost is much lower than yield/ output price i.e. reasonably / very profitable, called '***suitable***';

U= Crop/ vegetation/ fruit cultivation/input cost is expectedly/ reasonably higher than the yield /output price i.e. not profitable at all, called '***unsuitable***'.

F = **F**requently Cultivated at the time/decade referred, that is almost every year in the relevant seasons, generally Prak-kharif, Kharif and Rabi;

= shade indicates season/s of crop cultivation. There are three cropping seasons in Bangladesh.

M= Crop/vegetation/fruit cultivation/production/input cost is slightly lower than expectations of market prices thought by a farmer to be marginally /low profitable, called '***medium suitable***';

X = Yes is relevant to the suitability indicators i.e. either S or M or U.

O = **O**ccasionally Cultivated at the time/decade referred, may be one in every 3-4 years.

N = **N**o cultivation at or the certain crop almost or gradually disappeared as used to cultivate in the past.

(d) Shaal Baan and Shrubs (Forest)

One of the most important phenomena on the remotely sensed images in the early 1950s was the presence of deep shaal forest at that time (with some shrubs close to the villages where human interference was high). This was located almost entirely on chala land in the eastern part of the mauza, where currently Jahangirnagar University, Islam Nagar and Amm Bagan villages are located. The shaal forest gradually disappeared in the early 1960s when the area was acquired by the central government of East Bengal. Initially they planned here to establish a dairy farm, but in the late 1960s, when political trouble started in Dhaka University, the government decided to shift that university to this region to avoid political unrest in the heart of the capital. A small village community was affected by this acquisition. In 1971, Bangladesh got independence, and Jahangirnagar started expansion and its influence became greater. The most remarkable land use change was the loss of the ecologically diverse and rich shaal forest of that time (Figure 6-32).

Figure 6-32: A dense shaal forest (left) was dominated most of the chala lands in Savar, and nearby culture and society were highly involved with this rich habitat. By the 1960s, it gradually disappeared (right) due to the deforestation process.

(e) Jahangirnagar University (JU)

The current Jahangirnagar Campus has a massive influence on land use in and beyond its own territory. It is the residence for about 10,000 students and 2,000 staff including their family members. It generates economic activity everyday in the surrounding area. Bara Oalia mauza only contains 15 percent of the land of the total university. On the land use map of 2001, we can see 78 plots occupied with academic faculties and halls of residence for the students, administrative buildings, staff quarters for teachers and officers, a secondary high school, and lakes located on the previously known upper bydes. Some of the bydes are now cultivated by local farmers who have taken a lease from the university authorities. Moreover, there are some chala lands, where new plans are undertaken for the expansion of the university infrastructure.

(f) Household Pattern and Settlements (HH)

Bara Oalia mauza has a variety of housing types, from *mateer-ghar* to *pucca-dalaan* (mud-made/*lalmati* to brick-made). The earliest buildings are located on the outskirts or exterior of a chala. The settlement has then extended until its *dhala* (slope) begins. If we closely monitor the overall pattern in the early 1950s, the extent of the building was modest and they were very close to the permanent water bodies. Most of the agricultural fields were also not far away from the households. In comparison to the standard of the recent settlement status, most of the houses belonged to the category of rural low class in the early 1950s, with only a few exceptions of rural high class *ghars*. In 2001, most of the orchards are accompanied by buildings in the corner of a plot due to intense pressure of population over the old settlement area. Here, most of the orchards are comprised of Jackfruit trees and some bamboo-jhars. In 1951, only 6 small villages were present but now there are 9 villages including the JU campus. Apart from campus, Amm Bagan is the residential hinterland of JU middleclass staff, and Islam Nagar houses destitute refugees from river bank erosion.

We can classify the compounds into three major categories, with two sub-classes of each of them:

(1) **Rural Settlements (pre-development premises):** low (income group) class and high (income group) class;

(2) **Semi-rural settlements (developing premises):** low (income group) class and high (income group) class; and

(3) **Paura Settlements (pro-development premises):** low (income group) class and high (income group) class.

When I talked to a *Rajmistri* (a traditional builder) about his skill through practical experience regarding various housing phenomena of the different stages of development, he gave me a details idea which I have summarised in Table 6-8.

Table 6-8: Housing structures during the stages of development

Tentative Class	Pre-development Stage		Developing Stage		Pro-Urban Stage	
	Wall	**Roof**	**Wall**	**Roof**	**Wall**	**Roof**
Lower Income Class	Mattee-made (earth-made), *Katcha Dewal*	Chhan (Straw) and Bamboo made	Tin-made (adha-pucca)	Tin-made chhapra (aak-chala)	Brick-made, (*Pucca Dewal*, 5" thick wall), some time bamboo made (*Mooly Basher Berra*)	Tin-made roof
Middle Class	Mattee (earth made), *Katcha Dewal*	Tin Roof	Tin-made	Tin-made dwo-chala	Brick-made (10" thick wall)	Concrete Roof (*Pucca Chhad*)
Higher Income Class	Laal-matteer (two storied), *Katcha Dewal*	Wood-made first floor and tin made top floor	Tin-made (sometime more that one storied)	Tin-made chow-chala	RCC (Rod, Cement, Concrete) Made Wall (up to four storied)	Concrete Roof with RCC beam

Source: Based on interview with a builder, 2001

(1) Rural Settlements (pre-development premises)

The rural settlements are some of the oldest in this area, a few hundred years old. This sort of village is very common in rural Bangladesh. The general characteristics are the presence of very old mud-made houses engulfed by trees and homestead forests (see Figure 6-21 A). From the remote sensing images, such a village is a very dark in DN values, such as the old part of Oalia Mauza. There are no pucca roads in these settlements. In Barshakal (rainy season), only boats can be used and it then looks like an island because it is physically detached from the other villages. The village has electricity but no gas or running water supply.

This village shown in Figure 6-33 (B) is surrounded by palm trees, which indicates there has not yet been any urbanisation. Due to a high-density of vegetation cover, it is not impossible to locate individual buildings from the high-resolution satellite or aerial photos. But the context of the village land use can be understood. This village is situated on high land. Within a village, the vegetation cover is a mixture of trees, including jackfruit, mango, dates, barai, banana, and so on, and also small bushes and homestead cultivation (*paalan*). This village is connected by a katcha road. The common transport media are rickshaws and bicycles in the dry season and boats in the wet season.

(2) Semi-rural Settlements (developing premises)

Amm Bagan and Islam Nagar villages are new and both dependent upon the JU campus. The compounds located here are still at the stage of developing. One of these villages, represented in Figure 6-33 (C), was a part of the dense shaal forest only forty years ago. Massive population growth has been responsible for deforestation in the area. Then the land was a very good grazing for cattle and was also used for arable. But, due to heavy population growth and working opportunities in the nearby areas, houses have been built. The lack of trees (or paucity) indicates an area that is relatively new. Migrants affected by the Padma (Ganges) riverbank erosion, twenty kilometres west from this area, have built this village themselves in the last decade. This area is isolated and has no utility services. Mainly middle-income educated workers live here. Because of the lack of trees or vegetation cover , in summer, the houses are very hot. In contrast, they are cold in winter. Only a decade ago, this was the most backward area of the upazila, but this land is now highly valuable and there are further development opportunities.

The village seen in Figure 6-33 D is the outcome of institutional expansion in the study area. The village is only a few decades old. The village is expanding from west to east. Most of the villagers are directly or indirectly associated with the nearby campus economy. There is no plan to control this expansion towards a lowland byde area, which is a very flood-prone area as well as a very fertile land. This is the new and eastern part of the Oalia Mauza.

(3) Paura Settlements (pro-development premises)

As a part of Savar Paurashava (municipality), the photo seen in Figure 6-33 (E) reflects the unplanned and the oldest and part of northern Ganda mauza. The construction is mainly of brick (walls) and tin (roofs). The inhabitants are involved with commercial activities in Savar Bazaar, an area including merchant communities and businessmen. Only two to three decades ago, it was largely rural. There are no good quality or easy access roads to all the houses but gas and electricity supplies are available.

Jahangirnagar Campus can be termed as a *paura* high-class area (similar to Figure 6-33 F) as there are all of the municipal facilities available as defined by the government (see chapter 2). The area is the only well planned residential area in the eastern part of the mauza. This high land was a part of the *shaal-baan*. The town was inaugurated in the late 1980s. It is made of bricks and concrete. The inhabitants are mainly relatively high-class and work in the university. There is a very good road to every house and gas, electricity and water supplies are laid on.

Various settlement types of Savar Upazila reflect different ranges of EM energies and phases of developments

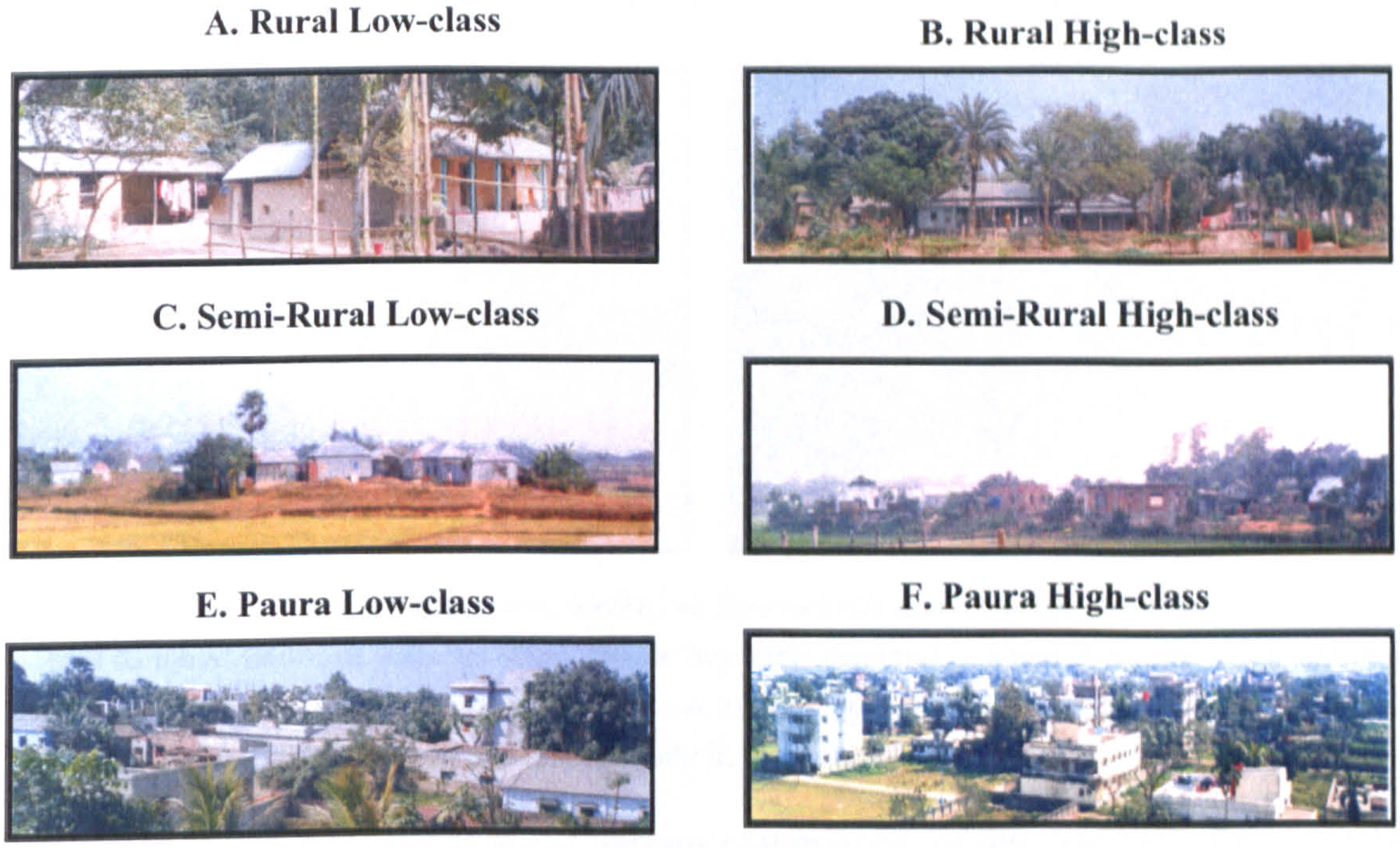


Figure 6-33: Not only from the land, also from the satellites, these settlements can be distinguished. All of the buildings carry their own economic status and spectral reflectance.

(g) Village Infrastructure (Infra)

In 1951, the important infrastructures were confined to only two categories visible at the plot level; these were religious places like mosques and local village shops (*katcha bazaar*), locally known as *tong-ghars* (Figure 6-34). But now there are several significant categories, as shown in Figure 6-23. For instance, there are several *pucca* roads in the east, semi-pucca roads all around the other outer boundaries of the mauza, as there are a number of water bodies. There are several small bridges made like box culverts, bamboo-made foot-bridges and medium size bridges. There is also a generator house established in 1978 in this village for supplying power to the university in case of main power failures but it has not functioned for more than two decades. There are several NGOs working in the area for sanitation, health, family planning, small credit and education for all. A kindergarten (KG) school is also established there, teaching in the English language. But apart from plot-oriented immovable properties, some modern technologies have also introduced in this region, like tractors for improved agricultural cultivation. A significant number of rickshaws are also a source of income for the locals or lower income migrants.

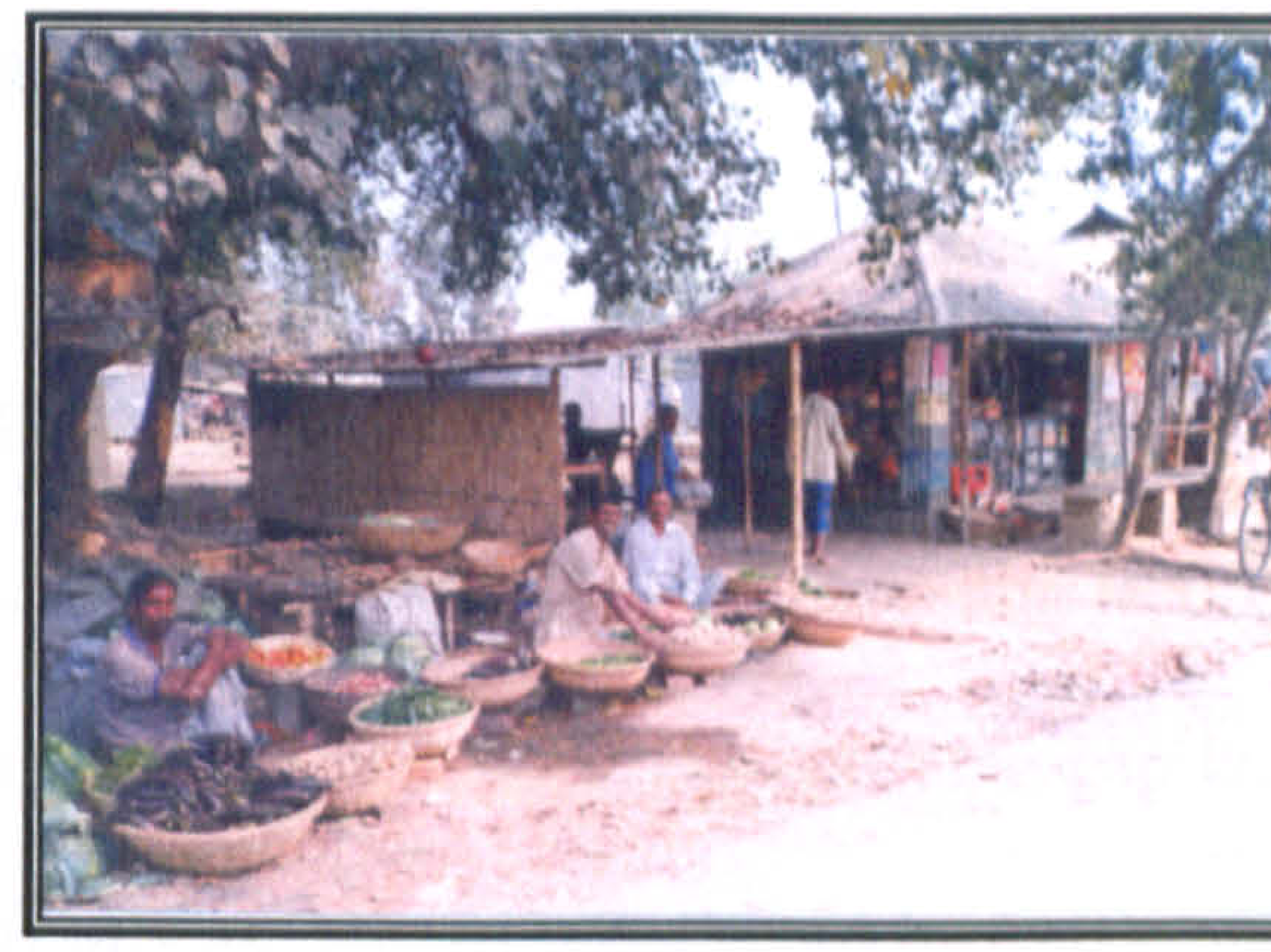


Figure 6-34: Village shops (*tong ghars*), located on the road side and on a slightly earth level. The shop is easy to move from one place to other. People buy their essential products from this shop, the shop contains a variety of goods from coca-cola, to food to medicine like paracetamol. The group of seated retailers are called *katcha bazaar*, and operate daily in the mornings.

We know at this stage the detailed various components of the land use of Bara Oalia mauza using a general and temporal discussion and also I have presented the photographic evidence where further clarifications were required. Now I will attempt an analysis of this land use by adding weighted information in order to see how the entire gravity of change is moving gradually, including the factors responsible for that.

6.6.0. 'Weighted Land Use' for Gravity of Change Analysis

At this stage, it is very important to know, how the impact of land transformation can be monitored. It is possible to do so using the major components of land types, villages located inside the mauza and based on land use parameters. All of them are essential to understand the complexity of the local micro-environment. But before going into further details, I will stress the significance of land values for the forthcoming sections.

(a) Weighted Land Use: Significance of Land Values

Land values have an important role in understanding the current, past and future trends of land use relevant to aspects of development and planning issues. Moreover, as there is no effective land management policy in Bangladesh to control land prices and use, they are determined instead by local factors. If we look at Table 6-9 and Figure 6-35, the inflation rate of money in respect of National Consumer Price Index (CPI) and Land Price Index (LPI) is distinctive. The CPI is monitored by the government agencies and I have proposed a LPI for Bara Oalia Mauza as an alternative for understanding a local context of the value of Bangladeshi currency since 1951 at the decennial interval. It seems that the CPI has inflated up to 100 fold over the last 50 years but the LPI has been increased up to about 13,000 fold. This extreme gap has encouraged estate agencies, land registration offices, *jomir-dalaal* (land brokers), and local *mustan* (musclemen) groups with direct or indirect involvement of the mainstream national political parities, because land-possession, selling and buying are some of the most profitable businesses or short-cut money-making tools for them in a relatively small amount of time and in comparison to other businesses. Bangladesh does not have a good geo-database of its land territory. The people sometimes sell off one plot three to four times to their buyers by cheating. This is a very common problem in Savar and a real danger for the overall development process of Bangladesh. Overall, land prices are most important in determining land use in Bangladesh and also may help to transform a plot from a rural to an urban land use. Also, knowledge of land values at plot level will help to quantify the land use data in order to calculate the weight of each land use component.

(b) 'Consumer' versus 'Land' Price Indexes (CPI vs LPI):

If we carefully observe Table 6-9 on the Consumer Price Index of Bangladesh and the Land Price Index of the surveyed Bara Oalia mauza, we can get a comparative picture of the value of Bangladesh Currency (in Taka) since 1951.

Table 6-9: **A comparative picture of CPI for Bangladesh and LPI for Bara Oalia mauza**

Population Census Years	*National Consumer Price Index (CPI)**	*Bara Oalia Land Price Index (LPI)***
1951	1.00	1.00
1961	2.07	2.48
1974	7.98	16.25
1981	23.76	56.92
1991	57.94	2,659.49
2001	100.16	12,600.59

*Sources: Calculated from *Statistical Year Books of Bangladesh and **Fieldwork data, 2001.*

Notes to Table 6-9:

(*) The CPI data were calculated from the Statistical Year Books of Bangladesh for 1974, 1994 and 2001 and published by the Bangladesh Bureau of Statistics. The considered variables of the consumer price index are based on food, beverages, tobacco; clothing and footwear; gross rent, fuel and light; furniture, furnishings and household equipment; medical care and health expenses; transport and communications costs; recreation, entertainment and cultural services; and miscellaneous goods and services.

(**) The LPI data were calculated based on the total land value of land in Bara Oalia Mauza with 1951 as the base year. The last row of Table 6-4 shows the original data of the mauza. As already mentioned, the land values are collected during fieldwork and total price of the mauza land was calculated using GIS approaches.

When I discussed with the villagers and local people the reasons behind the temporal and spatial variations of land values of a plot in a village, they mentioned several factors, as summarised here:

(1) Types of land, high or low; this determines the rough land use pattern;

(2) Access to nearby shopping centres like huts for marketing products and buying essential things;

(3) Soil Fertility and flooding conditions and their duration;

(4) Distance from educational institutes and other social services;

(5) Access to a main road, mainly pucca;

(6) Number of nearby job opportunities current/future;

(7) Distance from the nearest urban area;

(8) Links to national highways;

(9) Future prospects of the current land, e.g. if there is no gas supply, how soon it will arrive;

(10) Risk of river bank erosion;

(11) Risk of land acquisition;

(12) Density of population and households;

(13) Social structure of the current land users (higher or middle or lower income group);

(14) Presence of housing societies;

(15) Recreation facilities;

(16) Heritage, tradition and history of the land;

(17) Availability of household utility services (gas, electricity, water etc.);

(18) Transparency of land owners and land-record details, whether or not the buyer can trust the seller and avoid fraud.

They also mentioned that particular factors may play a very important role in one year but may not carry equal significance in the following years or vice versa. So the factors vary in time and space.

Figure 6-35 shows the total land value of Bara Oalia Mauza on a logarithmic scale. The price of land has increased very rapidly and much faster than the local currency inflation rate. An exponential trend line is also projected. So the state agency business is highly profitable in this part of the region as we can show the CPI trend with a general trend line while LPI is projected with an exponential line.

(c) Land Type-based Land Values

Table 6-10 summarises land type and land values data for Bara Oalia mauza. The mauza has mainly 5 types of land: high, medium high, medium low, low and very low. Each of these can be classified into two further divisions (Figure 6-36): Highland with *Shaal* forest and Highland without *shaal* forest (*Chala Jomi*) in the context of the 1950s. Due to the acquisition of *Shaal Baan*/forest by the then Government, the trees disappeared by the early 1960s. Medium High land and Medium Low lands depend on the top or bottom position of the bydes (narrow dissected lands) respectively. Lowland and very low land are located nearby or under perennial water bodies correspondingly.

Table 6-10 includes the total number of plots and occupied land in square metres and in Decimals of land. It also gives the total and price of the entire land type for a given year. The least valuable land in the 1950s and 1960s has become the most valuable land of the mauza nowadays. The highland prices have rocketed over the last three decades while medium lands and lowlands have been neglected, the opposite picture to the 1950s and 1960s. For example, on the one hand, the Highland (in column **A** in Table 6-10) shares only 8 percent of the land value of the mauza in 1961, in contrast to 1991 when it contributed 53 percent, while occupying 26 percent of the area. On the other hand, crop lands (generally columns **D** and **E**) contributed 70 percent of the total land value in 1961, falling to only 14 percent, although they occupy 40 percent of the territory. These findings raise more questions then we can answer at this point and they prompt an interest in people's perceptions about their land through time.

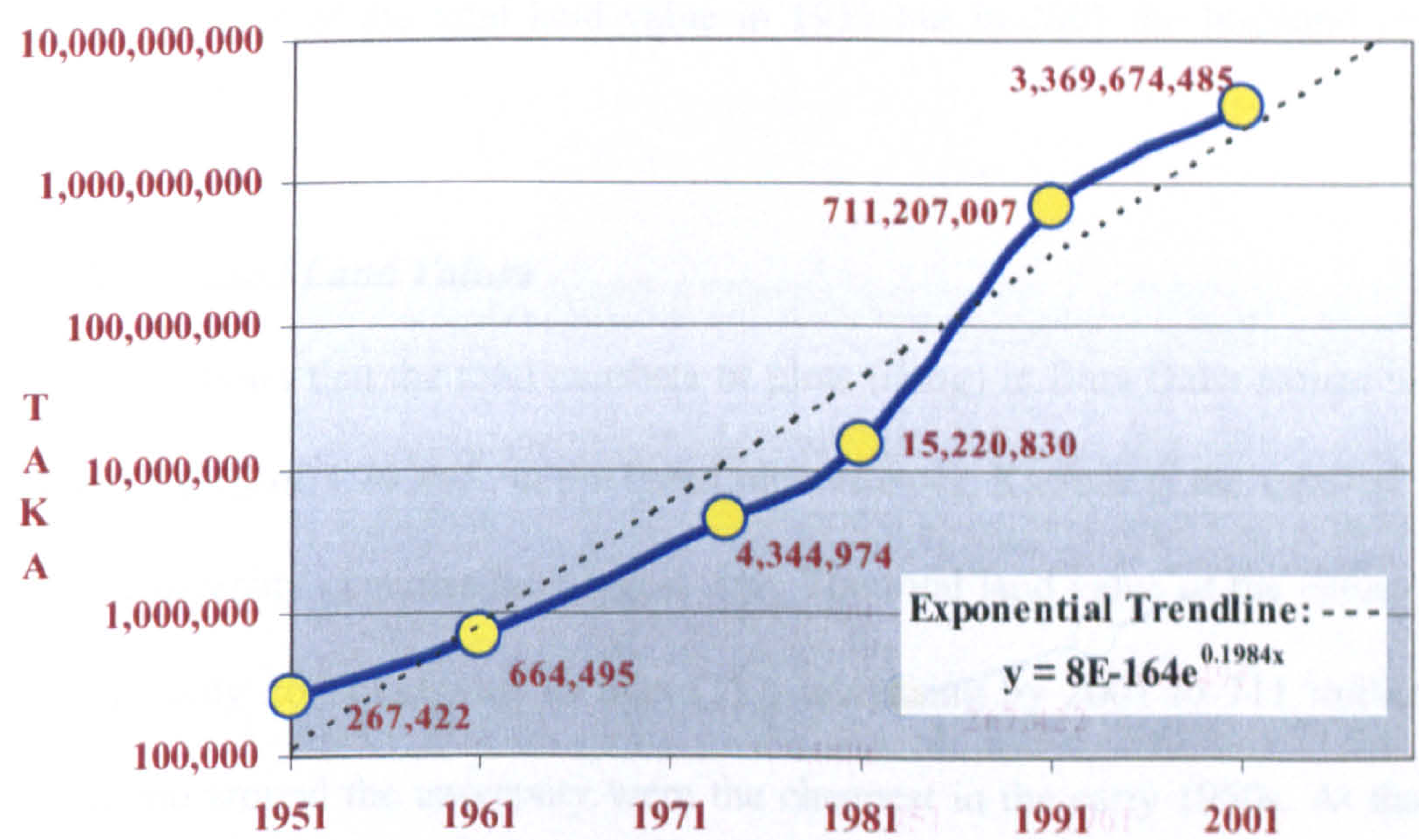


Figure 6-35: Land Value of Bara Oalia Mauza with its historical trend line. The X-axis is the year of land values considered and the y-axis shows the price of Bara Oalia mauza in local currency (taka) with a logarithmic scale. (Source: Field data collected in 2001)

Table 6-10: Land values of Oalia Mauza by land types since 1951

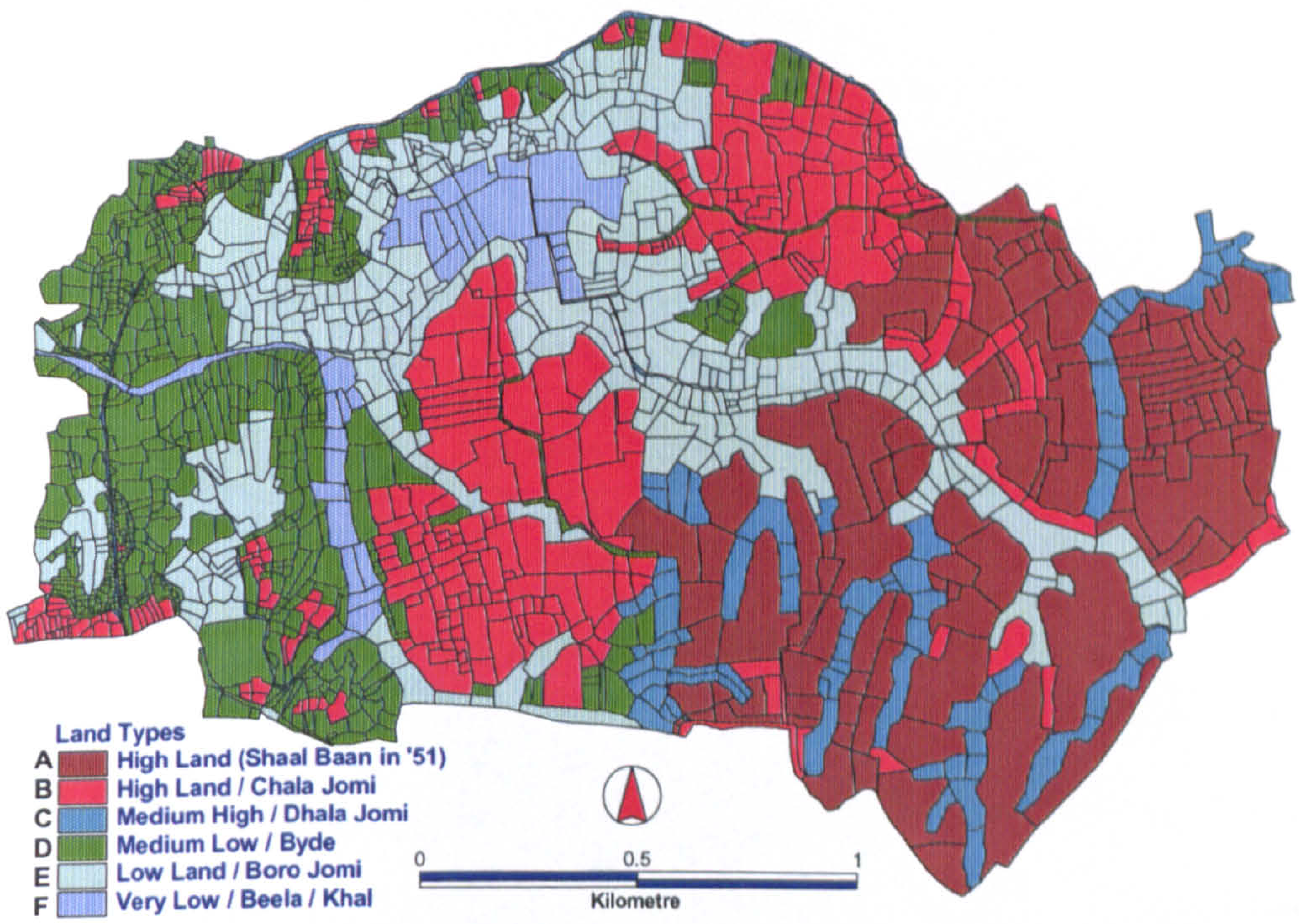
Land Types >>	High Land/ Shaal Baan	High Land/ *Chala Jomi*	Medium High/ *Dhala Jomi*	Medium Low /*Byde*	Low Land/ *Boro Jomi*	Very Low/ *Beela /Khal*	Mauza Total
	A	B	C	D	E	F	
Total Plots	117	339	88	607	361	35	1547
Area (metres^2)	963843	821186	273875	680427	840765	157749	3737846
Area/Decimal	23778	20259	6756	16786	20742	3892	92212
Area_%	25.786	21.969	7.327	18.204	22.493	4.221	100
Perimeter total	45037	67516	24708	86995	74426	10700	309382
Value_Tk_51	23780	76779	9519	45261	110135	1948	267422
Value_Tk_61	54802	122305	18804	269778	194916	3890	664495
Value_Tk_74	1072284	1602645	286974	856809	471915	54347	4344974
Value_Tk_81	6658492	3244335	1882719	1634048	1589837	211399	15220830
Value_Tk_91	378002485	158545110	72950270	63986536	35451205	2271401	711207007
Value_Tk_01	1729985060	931802590	299382210	252185630	150673090	5645905	3369674485
Value_%_51	8.893	28.706	3.563	16.914	41.177	0.726	**100**
Value_%_61	8.248	18.403	2.831	40.586	29.328	0.587	**100**
Value_%_74	24.680	36.878	6.607	19.723	10.865	1.249	**100**
Value_%_81	43.746	21.315	12.367	10.727	10.441	1.390	**100**
Value_%_91	53.150	22.289	10.253	9.000	4.979	0.319	**100**
Value_%_01	51.337	27.648	8.881	7.486	4.465	0.168	**100**

Source: Fieldwork, 2001

Figure 6-37 gives the balance of the land value over time. The lowland contributed about 35 percent of the total land value in 1951 but in 2001 the highland took that position.

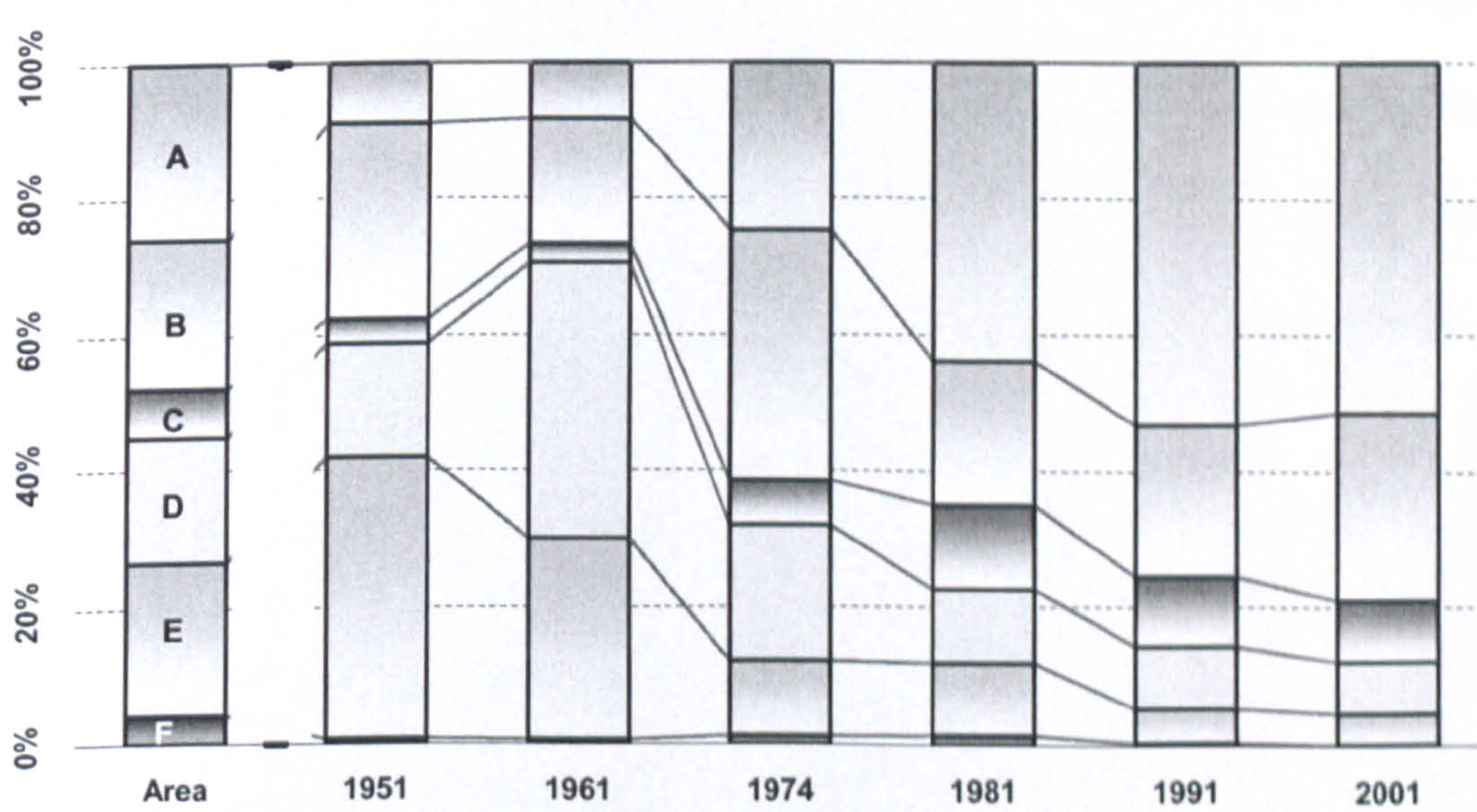
(d) Village based Land Values

Table 6-11 shows that the total numbers of plots (*daag*) in Bara Oalia *mauza* is 1,547, covering a total of 3.74 km^2. In the listed nine villages, Kasipur is the smallest village and the University occupies the biggest area. The total land value of the *mauza* (**K**) in 1951 was only 267 thousands of taka (Tk), increasing by 2001 to 711 million taka. Plots in and around the university were the cheapest in the early 1950s. At that time, the area was partly forested and as the area was mainly highland, it was not suitable for agriculture. Now, the area has good communications with the nearby capital Dhaka. Moreover, the university has all of the necessary modern urban utilities like roads, gas, electricity, mains water supply, drainage and telecommunications. Most of the eastern villages do not (or only partially) have these facilities or utilities. The whole scenario is reflected in the land values as the highest level.



Source: Fieldwork, 2001

Figure 6-36: Plot Level Land Type Patterns of Bara Oalia Mauza



Source: Fieldwork, 2001

Index : **A** = Highland (Shaal baan covers in the early 1950s which was later deforested),
B = Highland (Chala Jomi), **C** = Medium Highland,
D = Medium Lowland, **E** = Lowland and **F** = Very Lowland.

Figure 6-37: The graph shows the reflection of land values and their relative weight according to land types (left most bar which also represents total land as a %) over the last half-century in Oalia Mauza. The map illustrates the land types at plot level and their geographical distribution.

Due to inflation, currency devaluation, the 1971 war, and the rapid increase of land values and essential commodities, the local currency (taka) does not give the true picture of the spatial pattern of land prices over time (Table 6-11). By the total value in taka we can only get a relative picture about the land for a particular year. It is not possible to judge the land value over time in order to compare the historical changes on particular land types. That is why, land values are also shown in percentages for every village. The outputs are easy to show in GIS mapping in order to compare the weight of the individual plot throughout the time span.

Bara Oalia *Mauza* consists of nine villages: Pandua, Ammbagan, Jahangirnagar University (part), Islamnagar, Dakhin Oalia, Uttar Oalia, Kasipur, Boalia Para and Gakulnagar. The land values of the villages have changed in the last half-century. For present purposes, the total value of *mauza* has been considered as 100% for each year to give the absolute equal weight of each year in order to understand the importance of a particular village land spatio-temporally and also to assess the impact of land use or land cover since 1951. If we study Figure 6-41 (right-top) carefully, Gakulnagar village was the most influential village during the early 1950s and 1960s while the university has blossomed since the 1970s.

Table 6-11: Land values of Oalia Mauza by villages since 1951

Village >>	Amm Bagan	Boalia Para	Dakhin Oalia	Gokulnagar	Islam Nagar	Kasipur	Pandua	University	Uttar Oalia	Total
A	B	C	D	E	F	G	H	I	J	K
Total Plots	101	337	152	471	82	108	161	75	60	**1,547**
Area in %	10.907	9.362	12.790	16.688	13.769	4.858	12.386	12.323	6.917	**100**
Avg_Plot_size m^2	4036.5	1038.4	3145.2	1324.4	6276.4	1681.3	2875.5	6141.7	4309.0	**2416.2**
Area/Decimal	10058	8633	11794	15389	12697	4479	11421	11364	6378	**92212**
Avg/Decimal	99.6	25.6	77.6	32.7	154.8	41.5	70.9	151.5	106.3	**59.6**
Perimeter/metres	2,7121	43,662	34772	74692	28722	19487	38126	24911	17890	**309,382**
Value_Tk_51	16,078	30,588	32,850	72,177	17,425	14,670	47,492	13,049	23,093	**267,422**
Value_Tk_61	33,325	121,873	69,386	185,550	38,098	57,408	88,877	22,728	47,250	**664,495**
Value_Tk_74	141,239	471,125	546,082	693,248	159,787	257,499	378,029	1176,463	521,502	**4,344,974**
Value_Tk_81	662,929	728,207	1,382,314	1,429,248	637,068	524,821	994,650	7992,309	869,284	**15,220,830**
Value_Tk_91	153,742,955	27,316,480	74,355,990	45,562,915	84,791,455	14,524,800	44,871,310	236762,740	29,278,362	**711,207,007**
Value_Tk_01	463,279,200	95,823,090	454,796,480	196,199,295	572,168,110	61,244,560	232,617,270	1096591,900	196,954,580	**3,369,674,485**
Value_%_51	6.013	11.436	12.281	26.979	6.519	5.480	17.759	4.878	8.634	**100**
Value_%_61	5.016	18.330	10.443	27.922	5.733	8.638	13.374	3.421	7.106	**100**
Value_%_74	3.247	10.847	12.562	15.960	3.678	5.929	8.699	27.079	12.001	**100**
Value_%_81	4.354	4.782	9.084	9.386	4.183	3.443	6.531	52.510	5.713	**100**
Value_%_91	21.616	3.836	10.454	6.411	11.918	2.043	6.303	33.291	4.118	**100**
Value_%_01	13.749	2.843	13.495	5.818	16.976	1.818	6.901	32.541	5.844	**100**

Source: Fieldwork, 2001

Dakhin Oalia has had almost equal status since 1951, as it is the oldest and the most established village throughout its history. In the shadow of and influenced by the development activities of Jahangirnagar University, the adjacent villages gradually prospered more and more due to the constant increase of land values since the 1990s. In general, all of the western villages show a decrease of relative land weight, while western villages show a significant increase in weight. Dependence on agriculture and on the river or *khals* were the main pulling factors of the early 1950s in the west and since the 1960s the construction of the University and the National Highway are the factors which have amplified land value in the east of Bara Oalia *mauza* and helped immensely to boost the local economy overall.

(e) Importance for Mapping Historical Route of Gravity

Based on the land values, we can visualise the impact of transformation in numeric form and their temporal dynamisms. If we can georeference the land values of plots, then through geo-statistical techniques, it is possible to find out the centroids of a particular year and the gravity of change over time. If we can draw a line based on the centroids for different years, then it will show the spatial trend. We will try to explore the movement of centroids in space. Before calculating the statistical centroid of a mauza, it is important to know why this is important in the current context. This is because the main objective of searching for a focal point is not just to find the plot (daag number), where the centre of gravity is located but also to ask the following questions:

1. Where is the central neutral plot located? For example, if we consider, all plots of the mauza as priced at 1 taka per Decimal and there is no variation in plot price, what would be the ideal centre for the mauza? That means, there is no cultural or economic factor in action which may change its ideal physical centre.

2. If we add the real land value of the each plot, what will happen to the centroid? Will it be on the neutral point? If not, where is it located, and can we find out that plot? How far is it from the neutral centre? What is the direction from the neutral point?
3. What are the reasons for the variation of distance between central point and reference (neutral) centroid? Can we find the factors responsible for that? Can we plot the historical foot-print of the centroids? Some years the deviation is high, some years low. Why? Can we measure it?
4. Can we find out the depth of the direction (distance lines of 2nd and 3rd quartiles or 25th and 75th percentiles from the centroid and their variations along the centroids)? Is it possible to find out the focus of intense development? How can we visualise that? Is there any scale which can determine these matters? Can we see developing segments? What do they look like? Why is it important to find out? What is the nature of change over history? Does it help to read the past, present and the future?
5. What is the implication of this centroid method? Is there any real application in Bangladesh? Can remote sensing data give the perspective and explanation for it? Can we integrate the remote sensing image and social data for a better understanding of the land?

To get the proper response of the above queries, I need to explain the Box and Whisker method and how I used it with georeferenced coordinates. All data of the individual plots are here referenced with X Y coordinates of each plot centroid based on the LCC projection parameters as mentioned in the methodology section of this chapter with the ArcAvenue Script language.

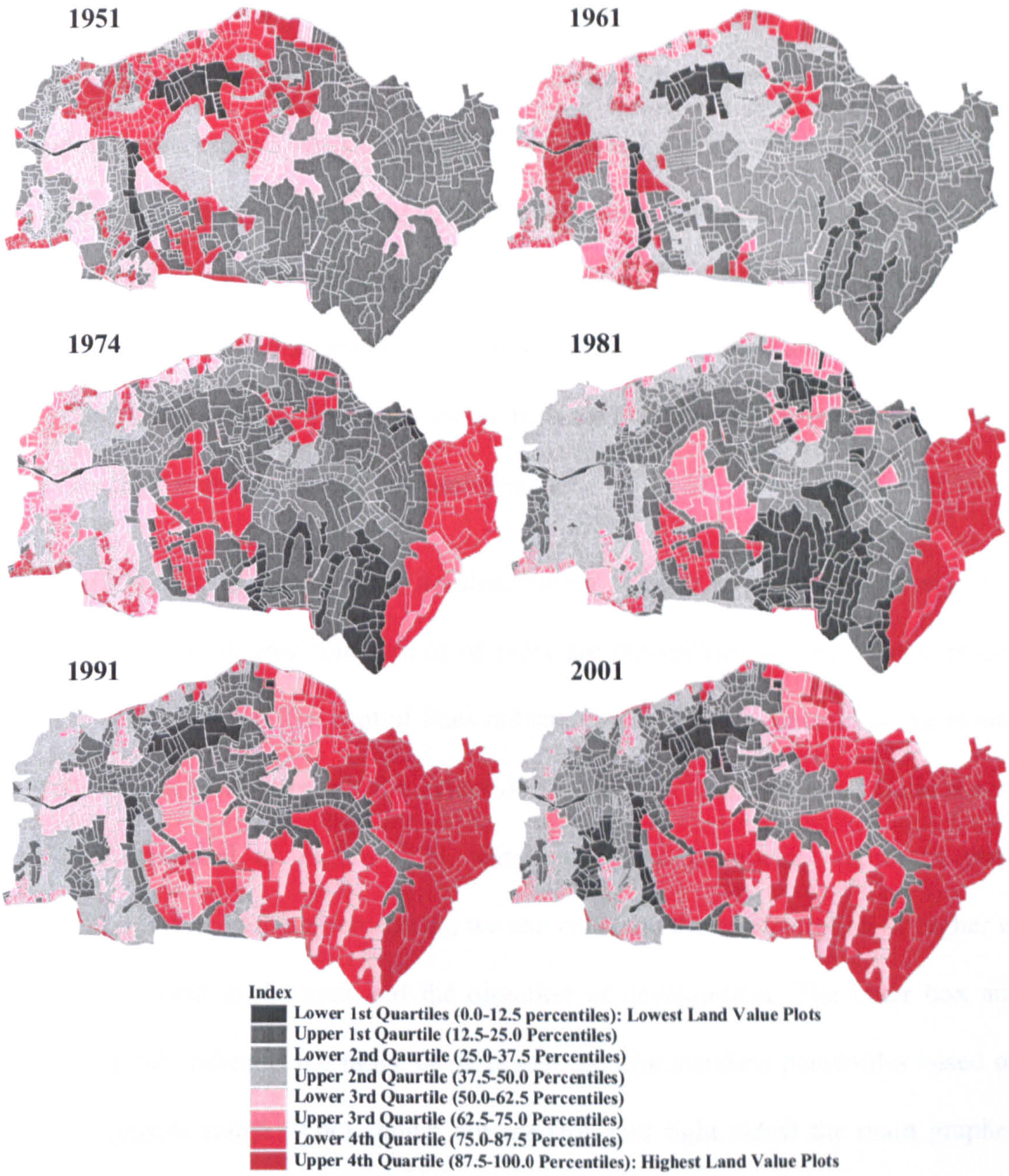


Figure 6-38: Land value distribution maps of Bara Oalia Mauza of 1951 to 2001 show the local complex factors in determining land values.

6.6.1. 'Georeferenced Box and Whiskers Method' for Gravity Mapping

I used the ArcView quantile classification methods for land value distribution in Oalia Mauza. Due to very high marginal values of land, standard deviation techniques were not suitable and so I used the box and whiskers method of the Stata Software, which is based on Quantile calculations for determining the centroid of a mauza. From the mauza we can see how the land type and location is important in determining land values for a particular plot. If we see Figure 6-38, it gives 8 categories of land values. These are the lower 1st quartile (0-12.5 percentiles), the upper 1st quartile (12.5-25 percentiles); the lower 2nd quartile (25-37.5 percentiles), the upper 2nd quartile (37.5-50 percentiles); the lower 3rd quartile (50-62.5 percentiles), the upper 3rd quartile (62.5-75 percentiles); and the lower 4th quartile (75-87.5 percentiles), and the upper 4th quartile (87.5-100 percentiles). The grey colour zones belong to lower half and red colour zone higher half of the mauza. The maps shown here are linked with Figure 6-39 for further classification for gravity and weight assessment.

The graph shows, in Figure 6-39, the distribution of plots according to the size and price of the land. Higher total prices of plots are represented by bigger circles and zones of concentration. The central lines indicate the land value centroid of the *mauza* in 2001. The outer line reflects the extent of 25th and 75th percentiles of Oalia *mauza* (in Stata command of Figure 6-39, xline and yline parameters represent these percentiles) Based on these percentiles, we can calculate the concentration of higher or lower priced land in the area and the direction of development. The outer box and whiskers graph indicates the range of particular data for standard percentiles based on the inter-quartile range (IQR) shown outside (top and right sides) the main graphed box or plotted area. The lines emerging from the box are called the whisker and they extend to the upper and lower adjacent values (i.e. between 25th and 75th percentiles). The deep grey tones of both sides reflect the higher priced land areas. We can also see the direction of shifting land weights for the particular year. In this case the *mauza* is more pro-eastward in comparison to its western lands. At the policy level, the eastern area should get the highest priority for an immediate development planning. It is more likely that the eastern zones will be urbanised shortly while western part will take a long time to reach that position. Moreover, the western part might play a significant role by improving its agricultural and water resources to feed the urbanised area.

It is obvious in Figure 6-39 that A, B, C and D are the centripetal quadrangles. It is interesting that E and F carry more weight than that of C and D. If we consider which rectangles should get the development priority in weighted order, the sequence would be: A > B > E > F > C > D > G > H > I > J > K > L. If we compared the situation now with that in the 1950s or 1960s, the picture would be completely different. The temporal scale contains the history and socio-economic development background of the area, which remains hidden in the decennial database of land values of the area. That is why land values are important and underpin the overall objectives of the present research. In case of Oalia, since the early 1980s, the tendency is more towards tertiary economic activities replacing the dependency of the local economy until the late 1960s on the primary economic activities. The local economy was balanced between both economic activities during the 1970's, and that should be considered as the turning point of the *mauza*. Higher prices reflect the popular demand for land and that is not constant but highly variable over history.

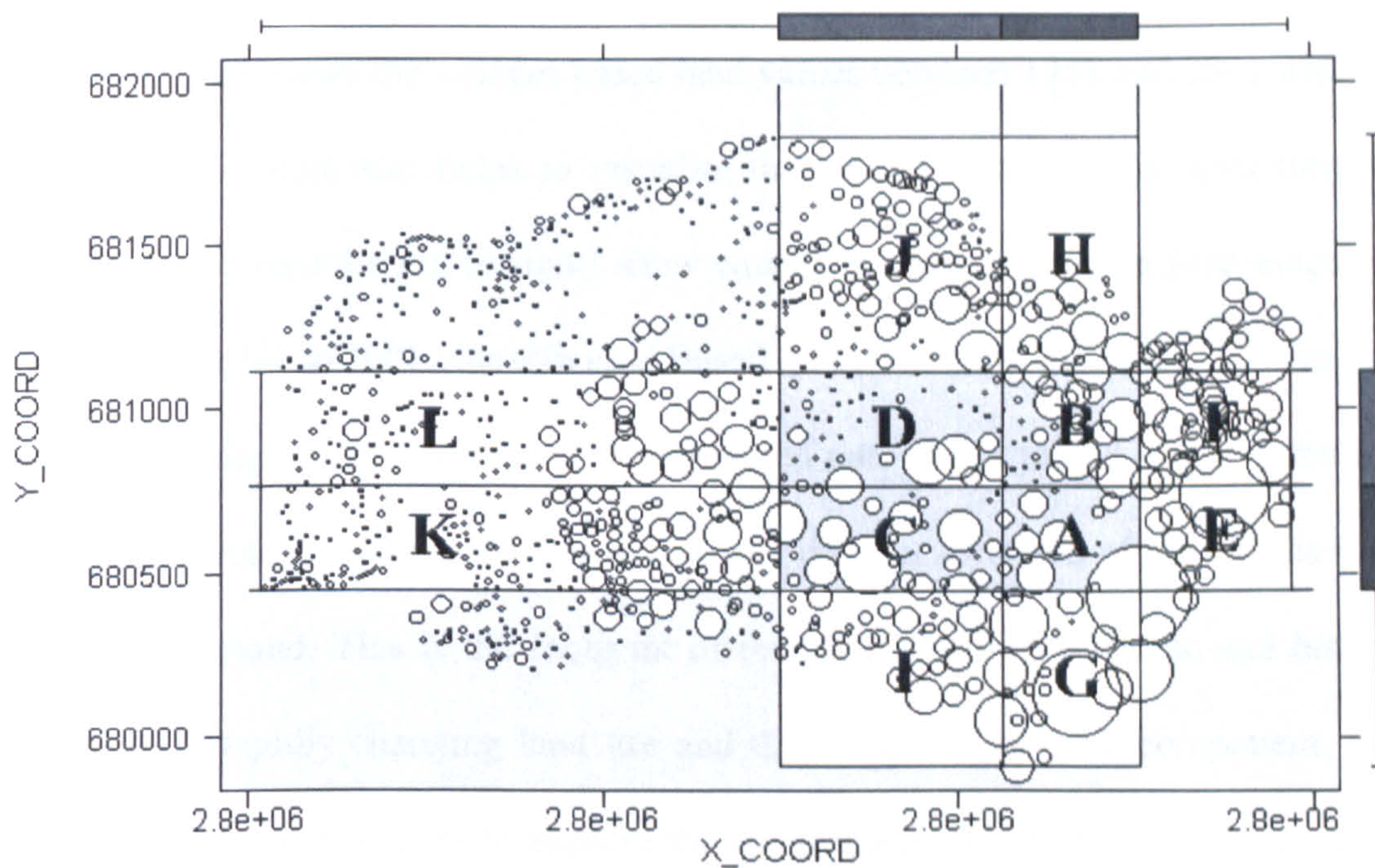
Table 6-12: Mauza centroids or omphalos in terms of land values.

Year	Lambert Conformal Conic X Grid Coordinate *In metres*	Lambert Conformal Conic Y Grid Coordinate *In metres*	Distance from Reference Centroid *In metres*	Direction from Reference (Neutral) Centroid	Distance from Immediate Past land-value Centroid *In metres*	Direction from Immediate Past land-value Centroid	Revenue Survey (RS)Plot Number *Haal Daag*
A	B	C	D	E	F	G	H
Ref. Centroid	2769509	680899	n/a	n/a	n/a	n/a	1509
1951	2769265	681011	278	North-West	278	North-West	1050
1961	2769108	680979	540	West	305	West	1031
1974	2769520	680891	140	West	418	East	1062
1981	2769982	680823	829	East	963	East	1689
1991	2769991	680848	670	East	162	West	1839
2001	2769960	680794	627	South-East	108	South-East	1836

Data Source: Fieldwork, 2001

I have also calculated the same for all other census years, but for comparison with the base line information, I show the map for 1951 (Figure 6-40). This indicates that the central focus was then further to the north-west part of the mauza. The eastern university part was then almost valueless. The western fragmented agricultural land carried more economic weight in general.

In Table 6-12, the mauza polygon area centroid is calculated based on X and Y Lambert Conformal Conic (LCC) Coordinates and weighted by the total area of all the 1547 individual plots of Bara Oalia Mauza. This point is a constant as well as a reference (neutral or weightless) value for all observations, and the distances have been calculated from this point in order to understand the influencing factors responsible (e.g. agricultural land, water bodies or land types), as well as directions from the origin (reference point) and the measure of dispersion (distance between the reference point and weighted centroid of a particular year). The plot-area based median XY coordinates are mentioned as the mauza or central or constant centroid, as the physical size of the area always remained unchanged. In order to measure the shift from the mauza centroid, the plot size is weighted by its plot value (price of the plot in local currency in taka) for the particular year. So the total weight of the plot changes over the time and so the distance and direction of the temporal movement can be calculated. The movement shown of is of two types: shifts from the reference point (column D), as well as from the immediate past land value centroid (column F). All values given are in metres and the directions are from north (column G). The biggest shifts occur in 1981 both from the mauza centroid and the land value centroid. To find out the geographical location of all centroids, the respective plot numbers or *haal daags* are also placed in column H. Figure 6-41 shows the LCC coordinates and the precise location of the centroid on the mauza map.

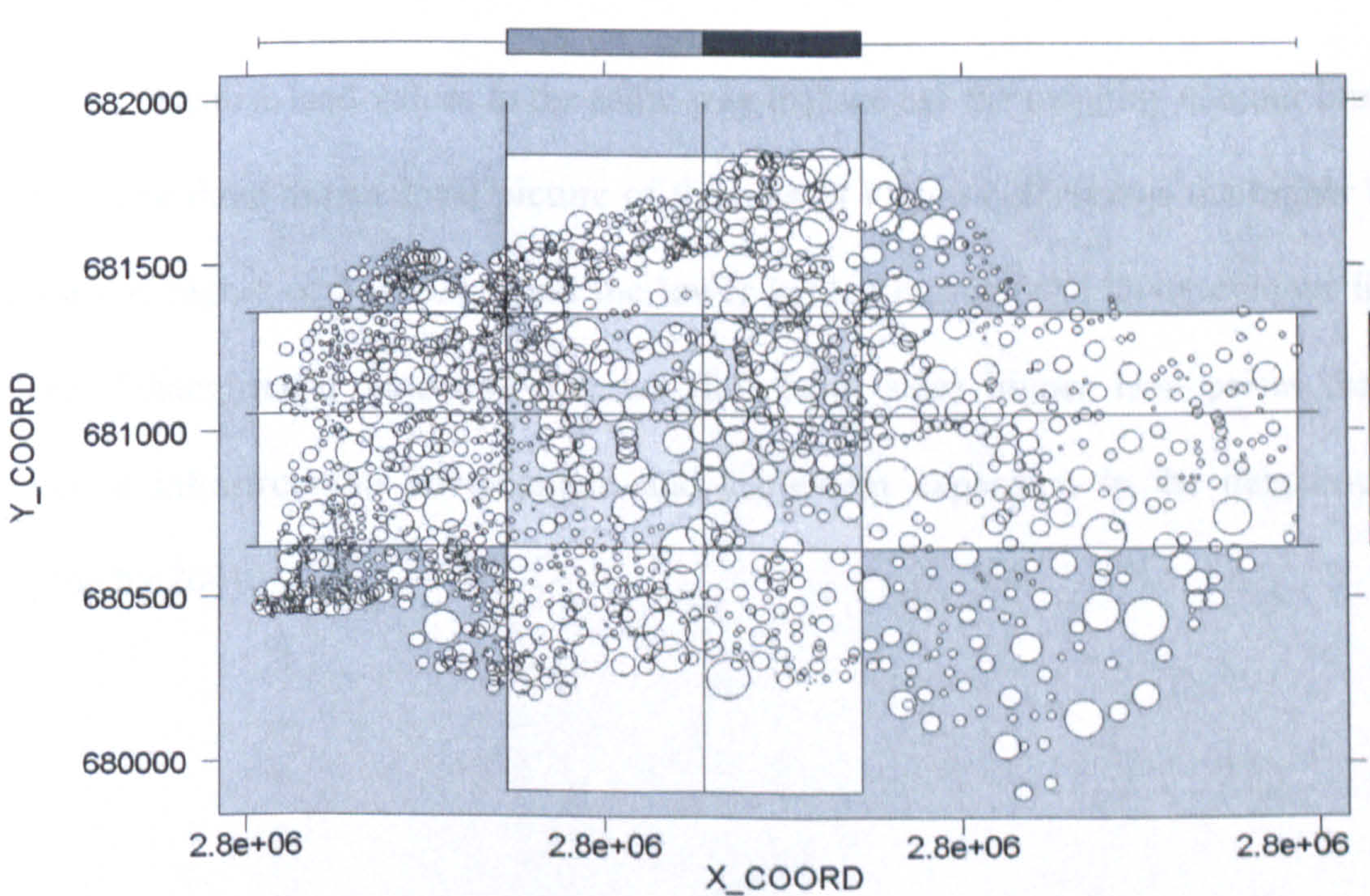


Source: Fieldwork, 2001

Figure 6-39: Calculation of mauza centroids and the surrounding rectangular segments for 2001. The outer bars illustrate the direction and depth of developing and under-developing zones.

Stata™ Command: su y_coord x_coord [w= plot_tk_01], detail

Stata™ Command: **graph y_coord x_coord [w= plot_tk_01], two box rbox ylab xlab border yline(680450.4 680767.3 681115) xline(2770123 2769495 2770512)**



Source: Fieldwork, 2001

Figure 6-40: Land value of 1951 of Bara Oalia Mauza using Box and Whiskers method with weighted two way plot value distribution.

Figure 6-41 illustrates the greater perspective of Bara Oalia mauza on the ADEOS image and also shows the villages based land values between 1951 and 2001 with a bar diagram. This chart map helps to visualise the weight of the village over time. The graphed bars (from the left to right) show equally weighted (price in percentage) land values from 1951 to 2001 respectively. Based on the centroid methods, in the enlarged box, the overlapped centroids have been pointed out. Now I joined all the centroids, a route of centroids has emerged and also shows the plot locations of Bara Oalia mauza in the background. This is the footprint of the transformation dynamic and historical legacy for a rapidly changing land use and the weight of its each component. In the following section, I will try to explore the basic reason for showing the ever shifting movement of the weight at decennial scale.

The following dot maps (Figures 6-42 to 6-47) do not show the context of the land value and land use change over time. In this case I have integrated the high resolution images to help to illustrate the context in Figure 6-41.

We can visualise land values in the same way that we use the mapping contour lines of relief. The three dimensional picture of the area in Figure 6-48 shows the higher land values as higher contour lines and the lower land values got the lower contour lines. Here, Jahangirnagar University shows (left hand side) higher land prices due to massive infrastructural development and settlement expansion in the neighbouring region by 2001.

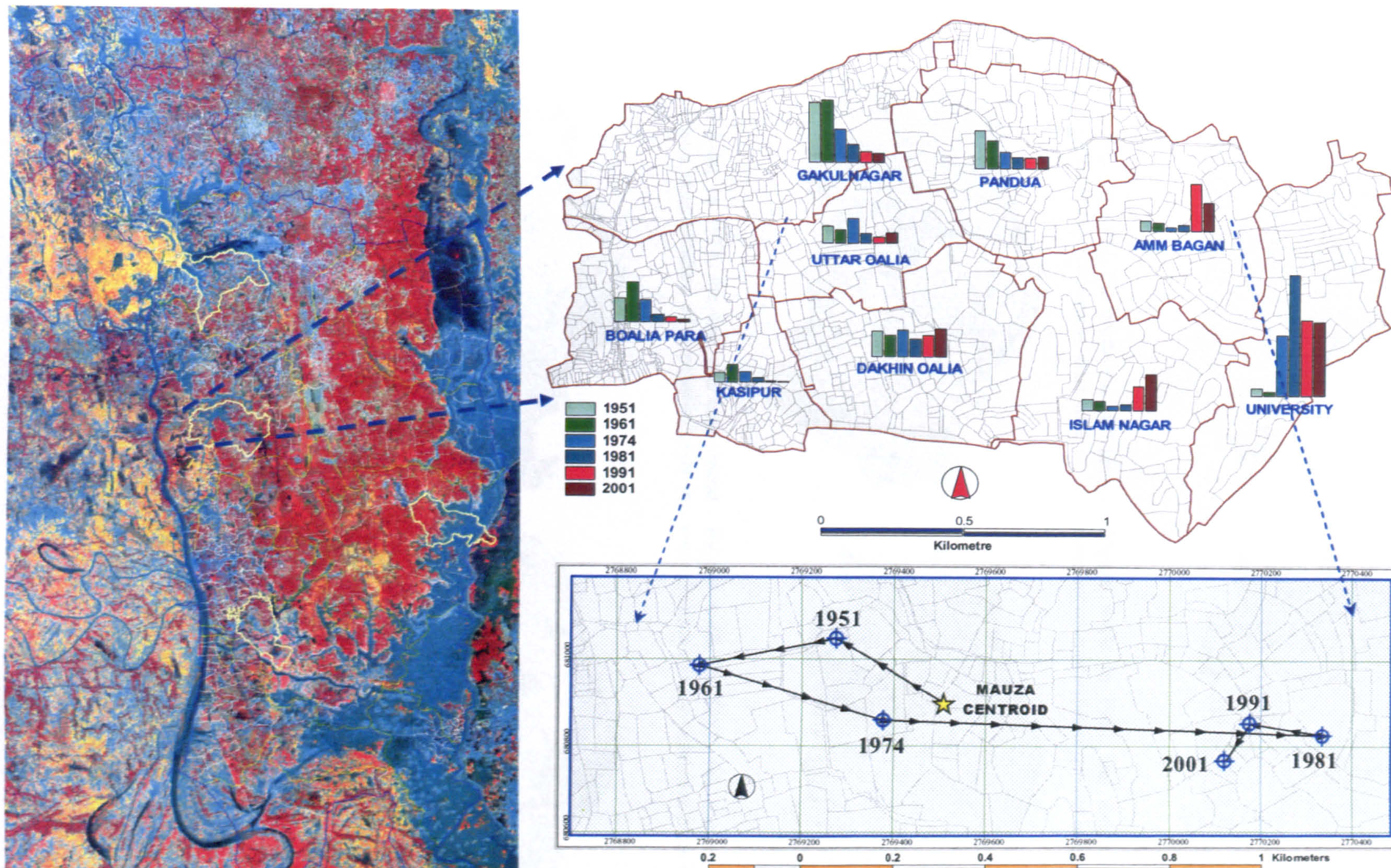


Figure 6-41: (left IMAGE) ADEOS Satellite image of Savar Upazila and the location of Oalia mauza; (right-top MAP) land values in percentage according to villages; (lower right BOX) Route of decennial centroids due to shifting focus of dynamic land values.

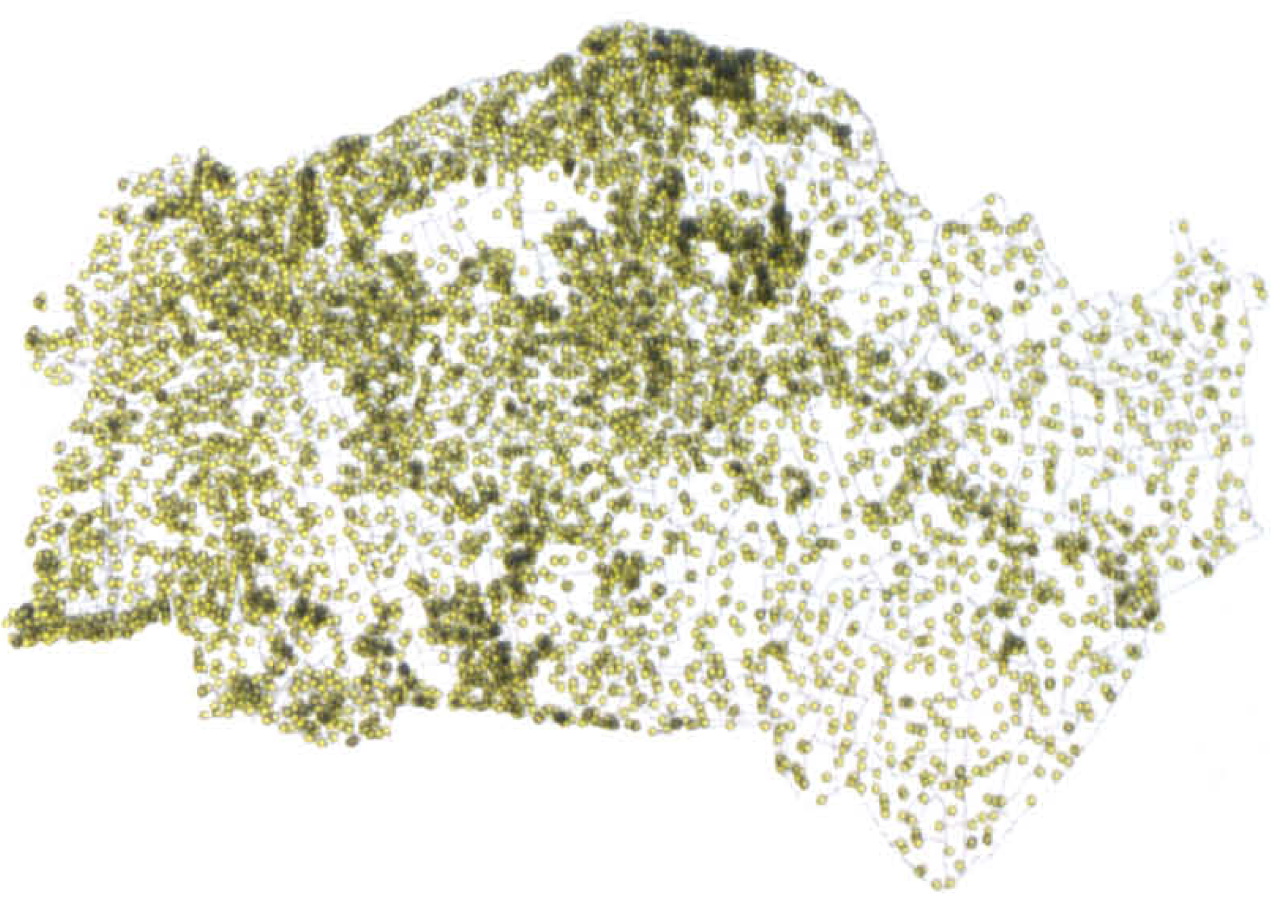


Figure 6-42: In 1951, the northwest part shows concentration of expensive plots in general

Figure 6-43: In 1961, the western part shows concentration of expensive plots in general

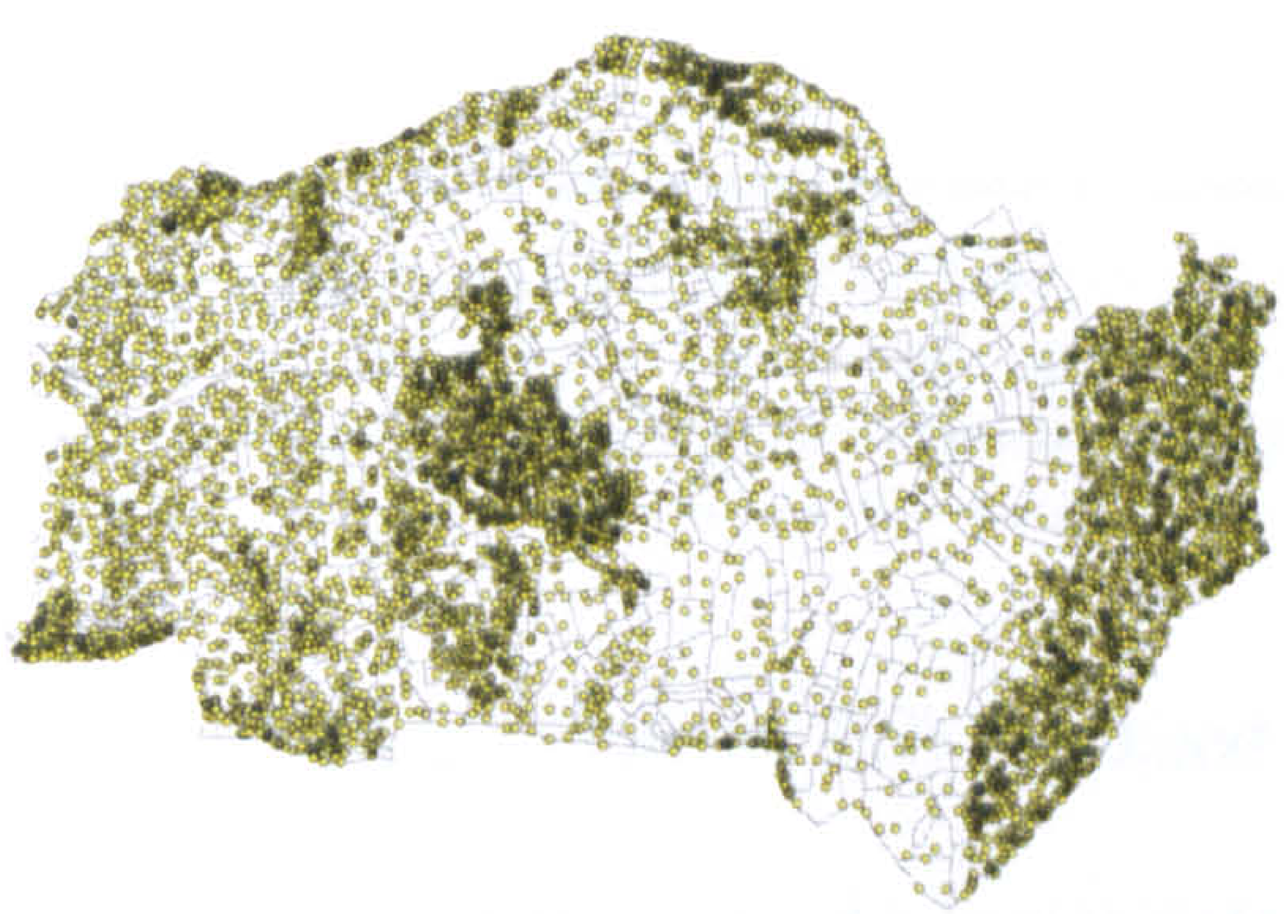


Figure 6-44: In 1974, the east and east-central parts shows concentration of expensive plots in general

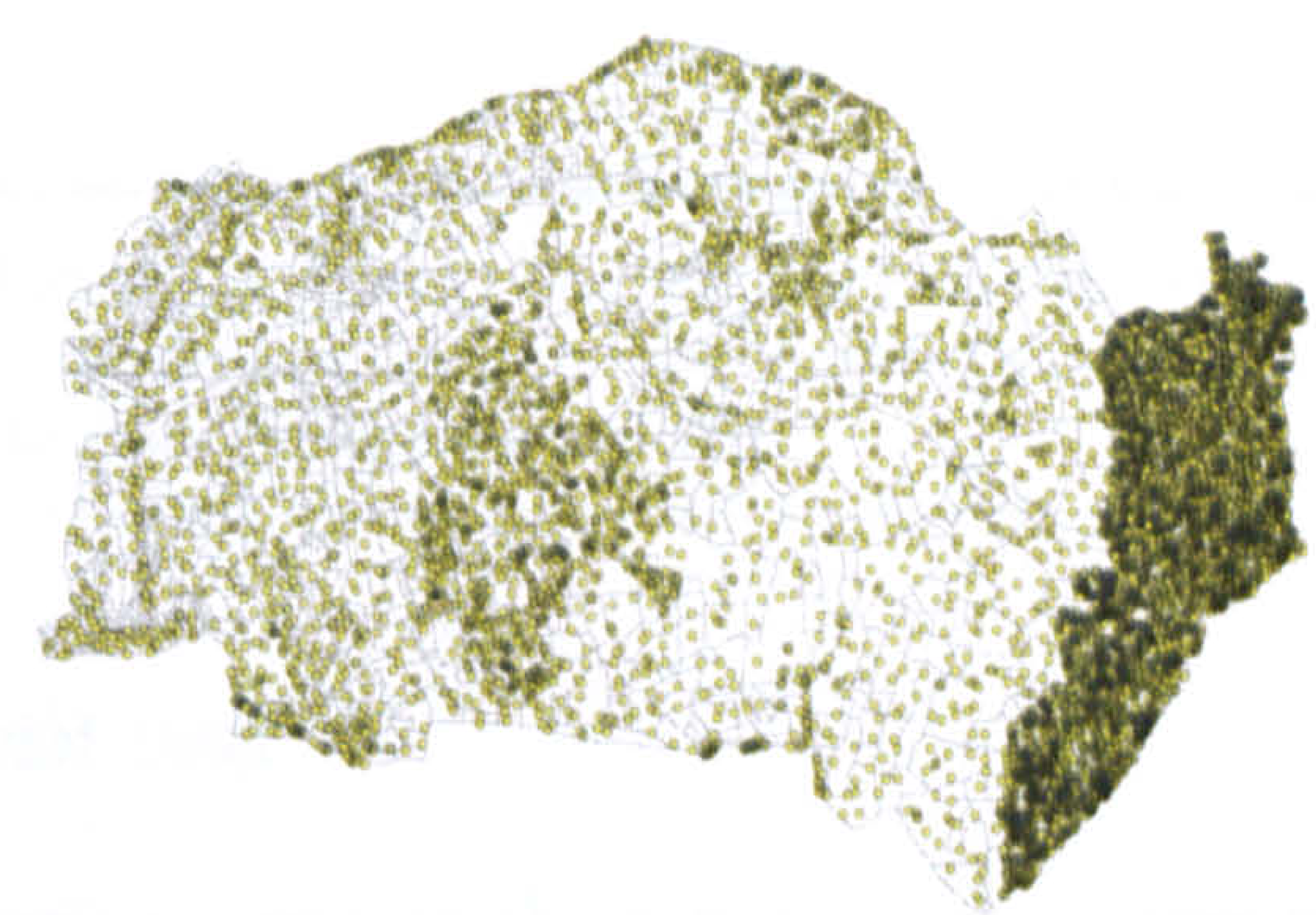


Figure 6-45: In 1981, the eastern part shows concentration of very expensive plots in general

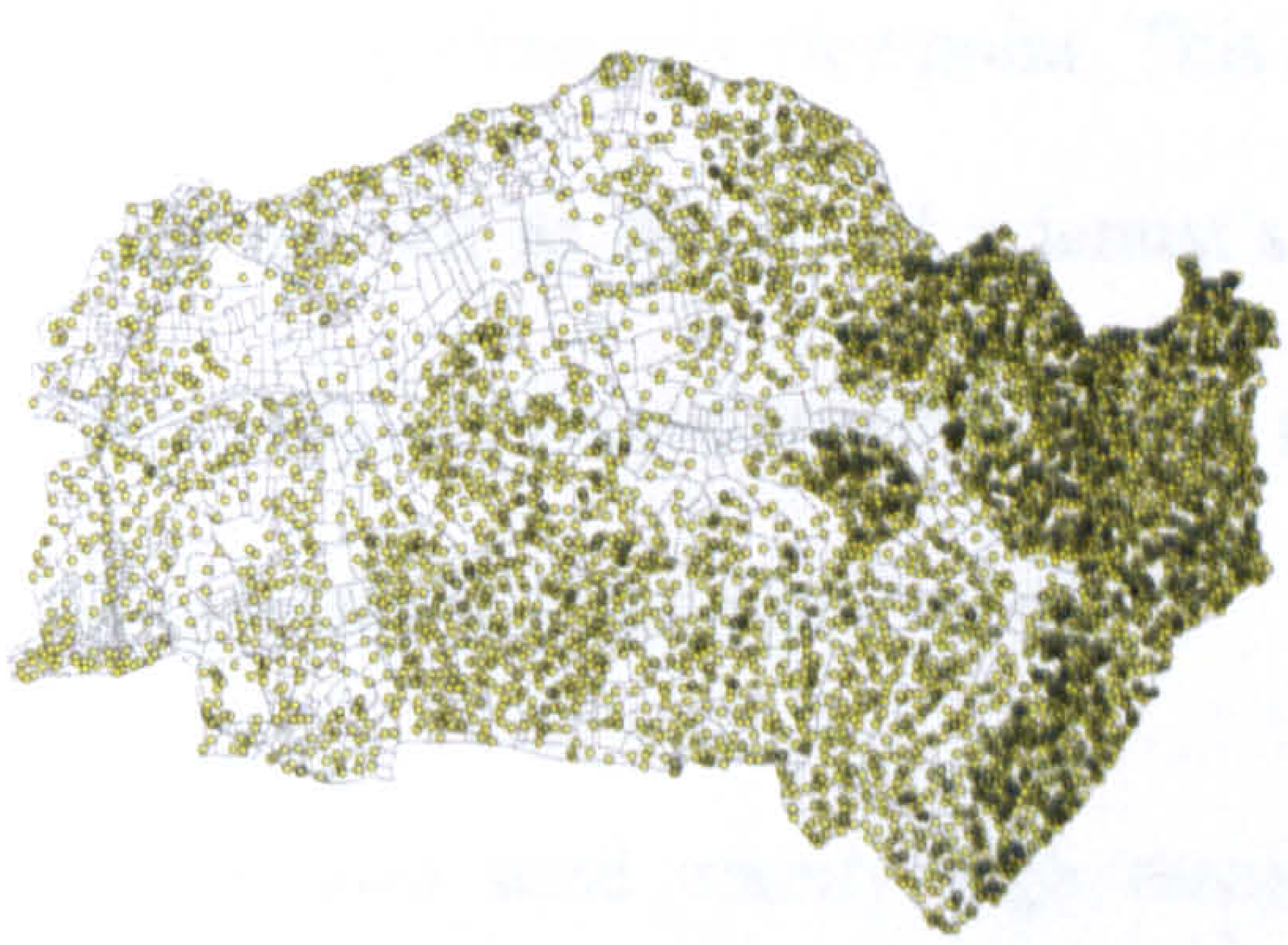


Figure 6-46: In 1991, the east and north-eastern part shows concentration of expensive plots in general

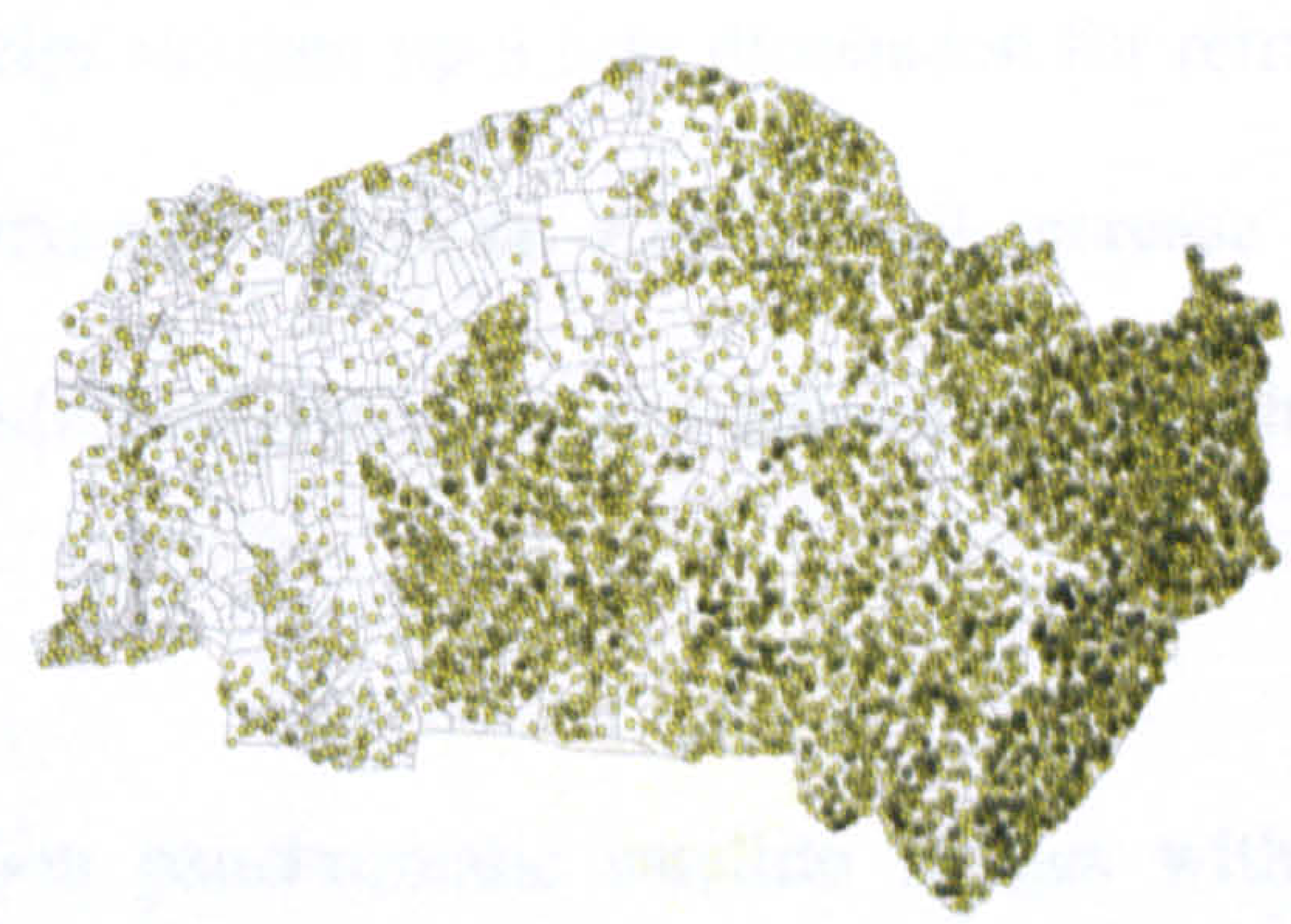


Figure 6-47: In 2001, the east and eastern and southern parts shows concentration of expensive plots in general

Data Source: Fieldwork, 2001

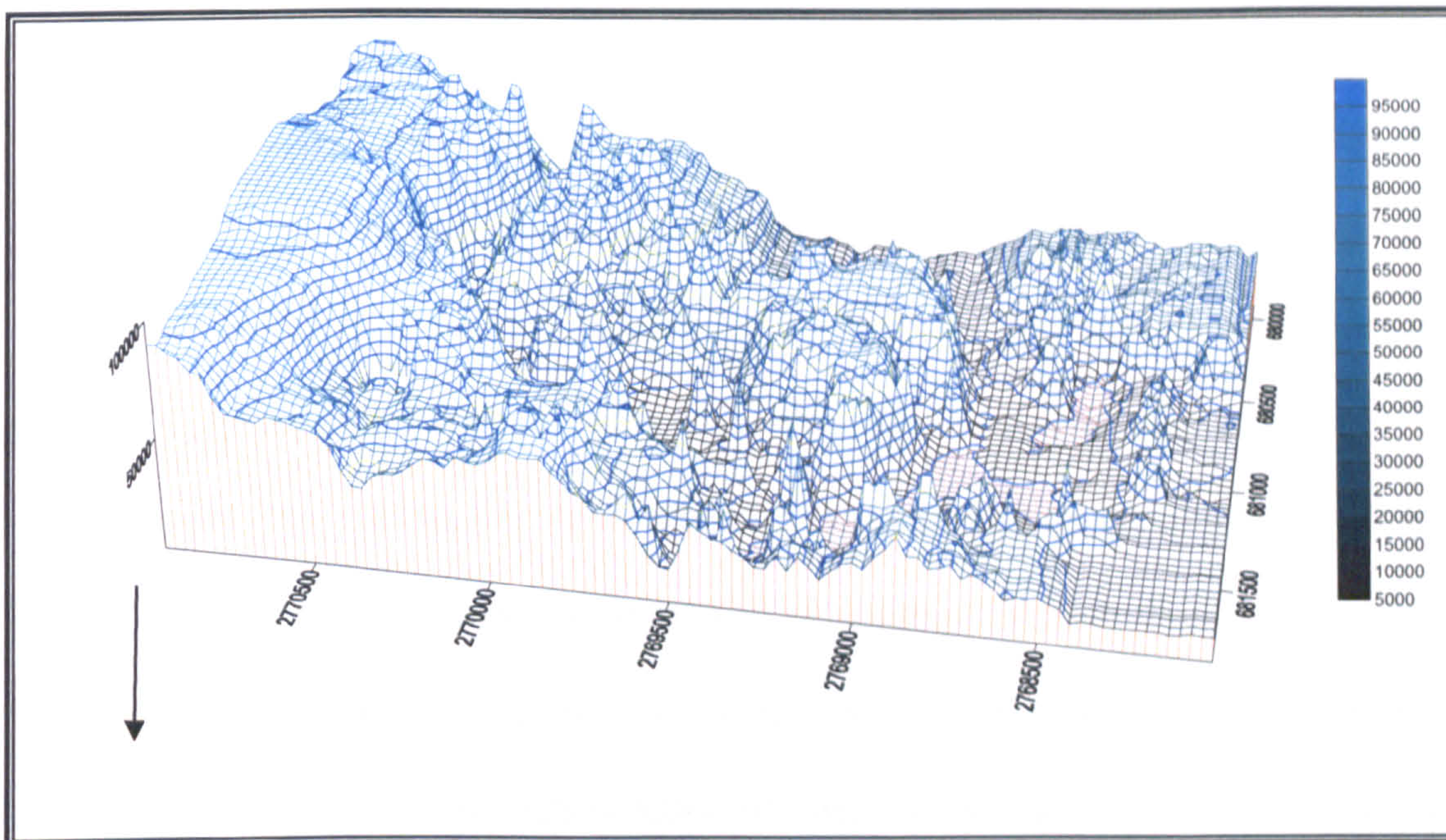


Figure 6-48: Simulated relief of land values of Bara Oalia Mauza. The left hand side shows the impact of the nearby university and the right hand part reflects the negative impact of underdevelopment. The legend shows the actual land values per Decimal in 2001.

6.6.2. Adding Values to RS: Pixelised Social Data

This is a first attempt to add social data or information to the remote sensing images after developing the same resolution data sets for them, in order to see the imagery from a social scientist's viewpoint. This helps to open up a new dimension for remote sensing as well as the social scientist's arena of research. Also it will increase the acceptability of remote sensing for the traditionally non-remote sensing fields which have maintained a distance from it.

So far I have used mainly high resolution panchromatic satellite images without integration of social data (or simply any data a satellite or aerial sensor cannot sense, in my case social data, particularly land values). To add social data in remote sensing, we need at least 2 bands (one for the image and one for the social data). For the multi-spectral image, we need at least 3 bands such as red, green and blue. But in my case, I used one band (red) for social data and a combined band (Turquoise or Cyan) with the combination of two bands (red + blue = Turquoise or Cyan) of remotely sensed data.

So Band 1 (red) was Land Value Data and Band 2 (green) & 3 (blue) were defined as a composite band made up of spectral data from CORONA or aerial photography. So, one band has been dedicated to the social data. For instance, band Red contains land values data at plot level while composite band represents the remotely sensed images where the context of the land value is visible. If we overlap the social and RS panchromatic data, we can see the distribution of social data on the image at the same time. This helps to understand the history of land values through the time, space and social dimensions. We have already interpreted all the RS images and have in-depth understanding of the spectral values reflected from the land and captured by a satellite sensor. Moreover, we have seen the spatial distribution of land values at similar resolution at plot level and the background behind them. Therefore, we got the opportunity to see the spectral and social meaning of Bara Oalia mauza. Social data cannot show the strength of the spectral reflectance while remote sensing data are unable to visualise the intangible part of the land surface, like land prices per pixel. By integrating both of them, there is a significant role for the both social and image analysts.

I mapped all of the decennial land value data on the image in Figure 6-49 to see a new dimension for visual and decision-making approaches. If we observe the prominent red colour (band) in the early 1950s, the land value is higher very close to or surrounding the water body, locally known as Oalia Beel. This was the only source of water for drinking, household activities and irrigation purposes in the dry period. Therefore the land values of nearby chalas and chwaks were very high. Water played the most important role in determining the price of land and land without access to water was not valuable in any context. From the 1960s to 2000, the total pattern and context has changed dramatically.

(a) In general, the advantages of the technique are:

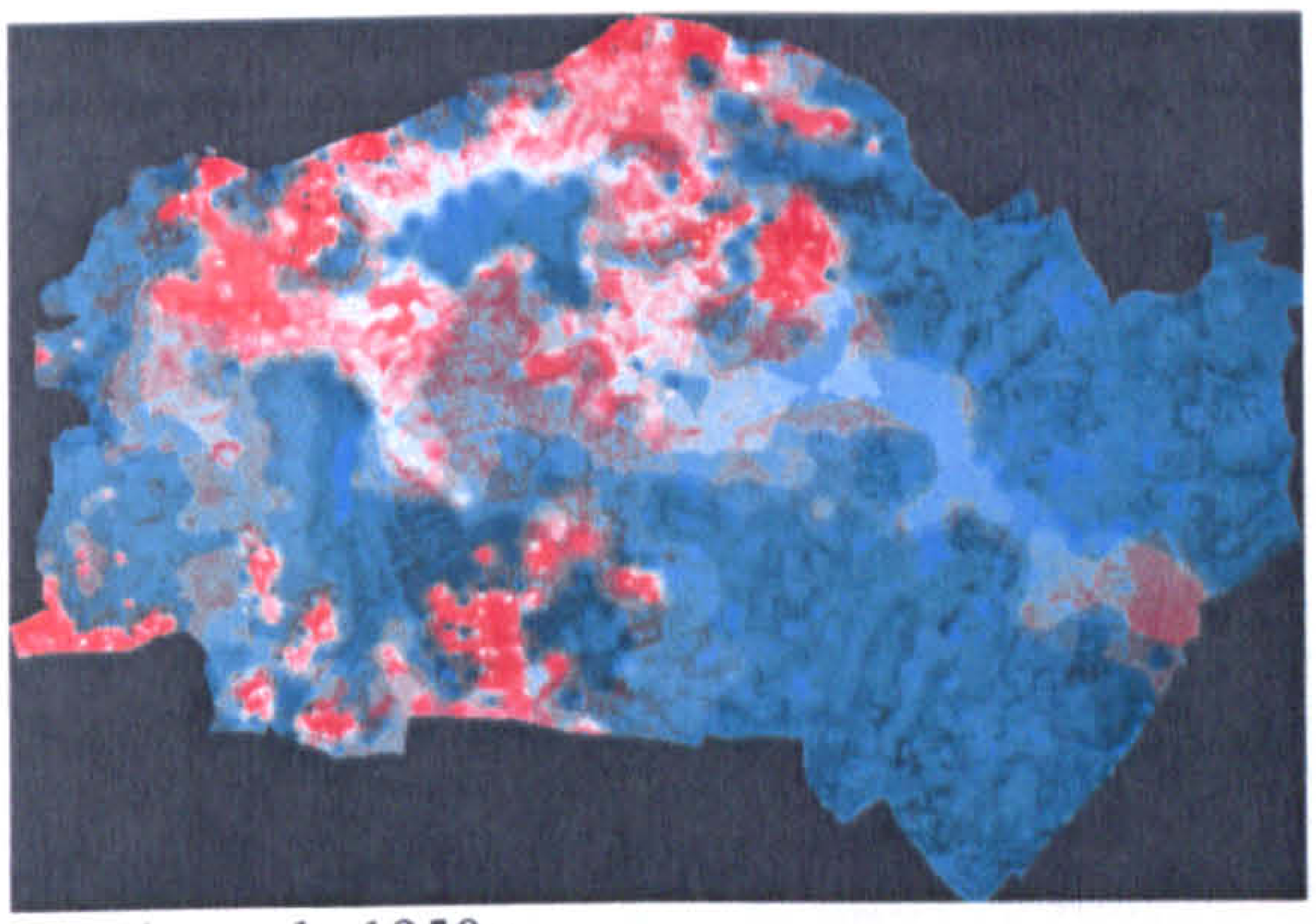
The techniques mentioned above are important in considering the following issues in general in the field of remote sensing for social researchers:

1. See the social data on the remote sensing images;
2. Understand the spatial dimension of the social data;
3. Find out ways of interpreting the pixels;
4. Monitoring the change over time and predicting future trends;
5. Helping boost the quality of social data;
6. Proper application of large scale maps locally available which have been underutilised to date;
7. Adding directly to the geo-corrected population and agricultural census databases;
8. Widening the use of remote sensing for the social scientists and other non-remote sensing fields.

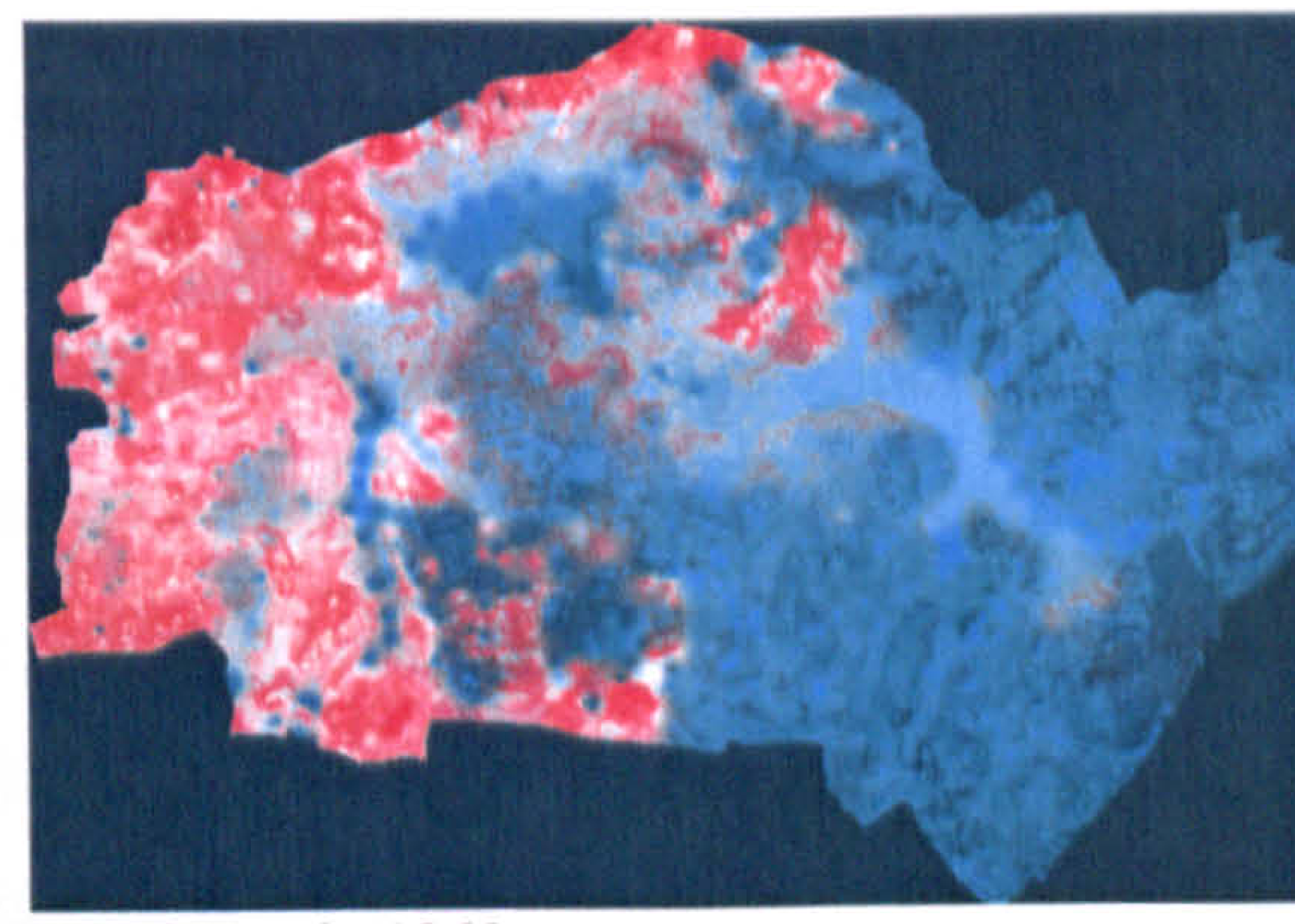
But if we think particularly about the benefits from the current research on Bara Oalia Mauza, the following section will give potential answers.

(b) For this particular example of Bara Oalia Mauza, the advantages are:

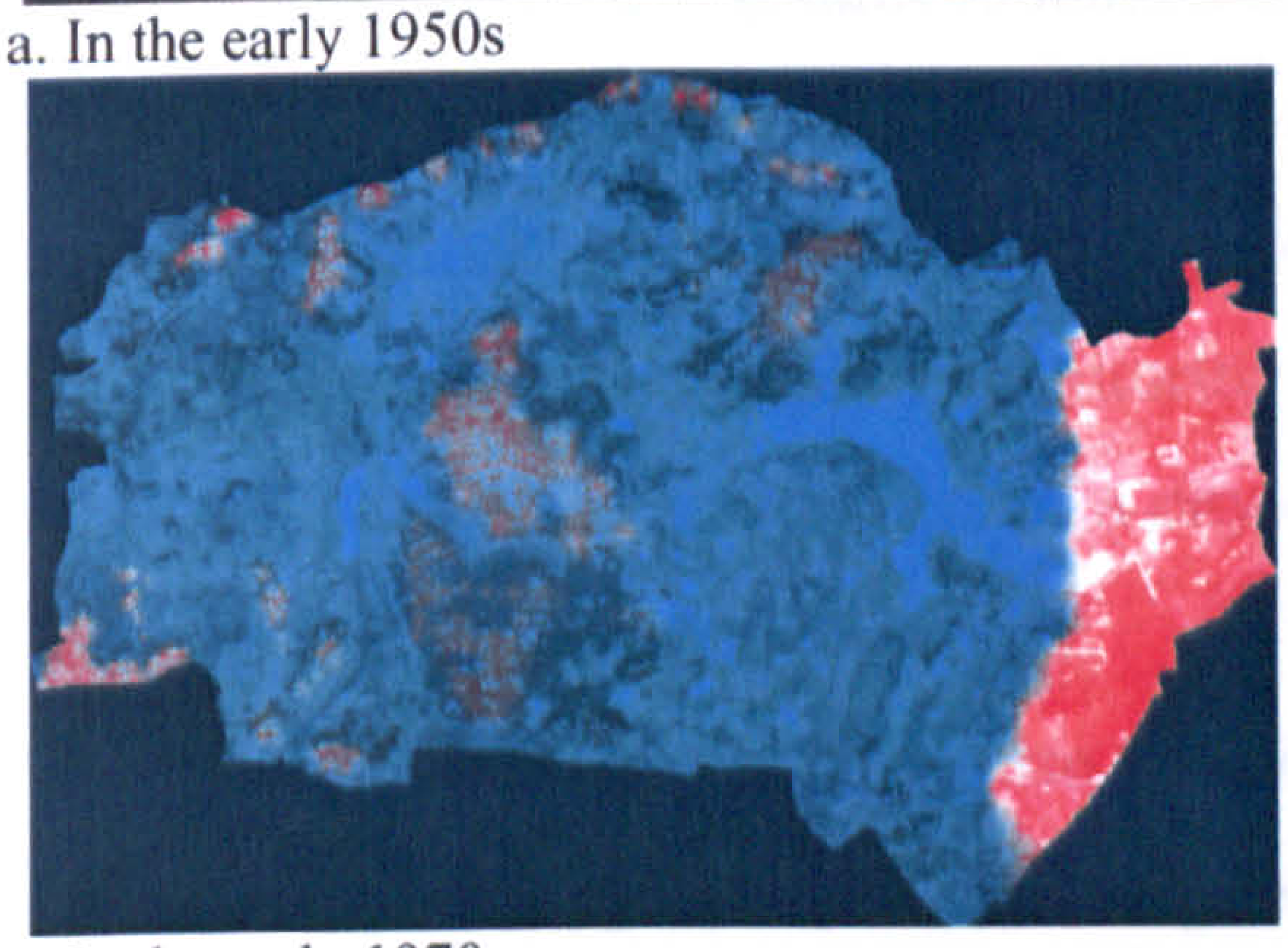
1. Use of a mauza map for the first time in Bangladesh where landownership attributes have been merged with the pixels.
2. High resolution satellite data allows explanation of the spatio-temporal factors that are responsible for its decennial changes. Without such a context, for the social scientists, it is very difficult and sometimes impossible to perform a detailed change analysis.
3. To see the practical micro-complexity both for the mauza maps and the Remote Sensing images, for example, how a beel (a natural lake) affects the surrounding chala lands and the expansion of settlements and how it also reacts over time. Without seeing this as an integrated image, it is less easy to identify the surrounding factors.
4. Physical factors can also be seen as relative phenomena, for example which has the more influence than others. For example are *chala* or *beels* more significant for triggering change? Historical images can help us in exploring such relative weights.



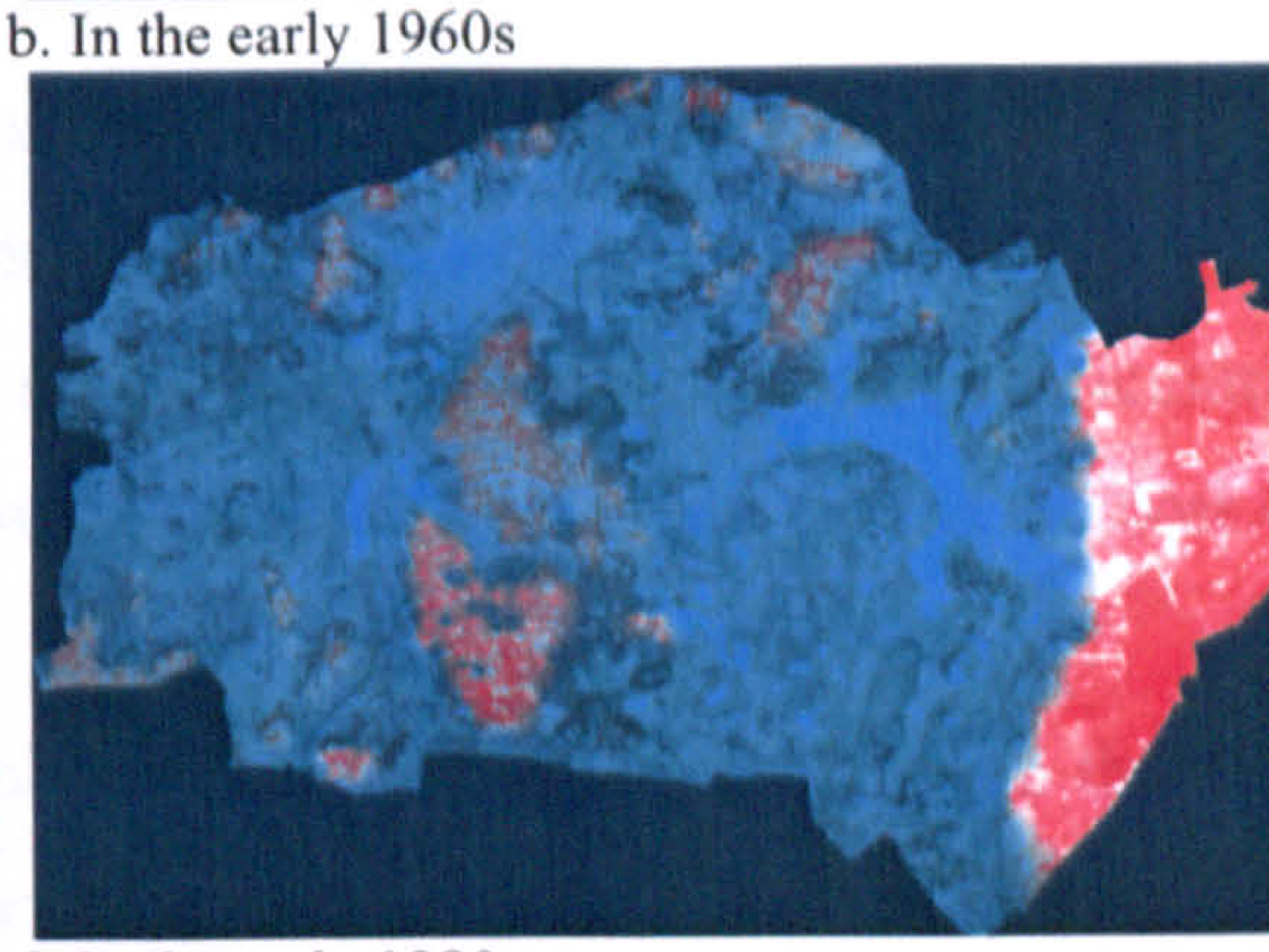
a. In the early 1950s



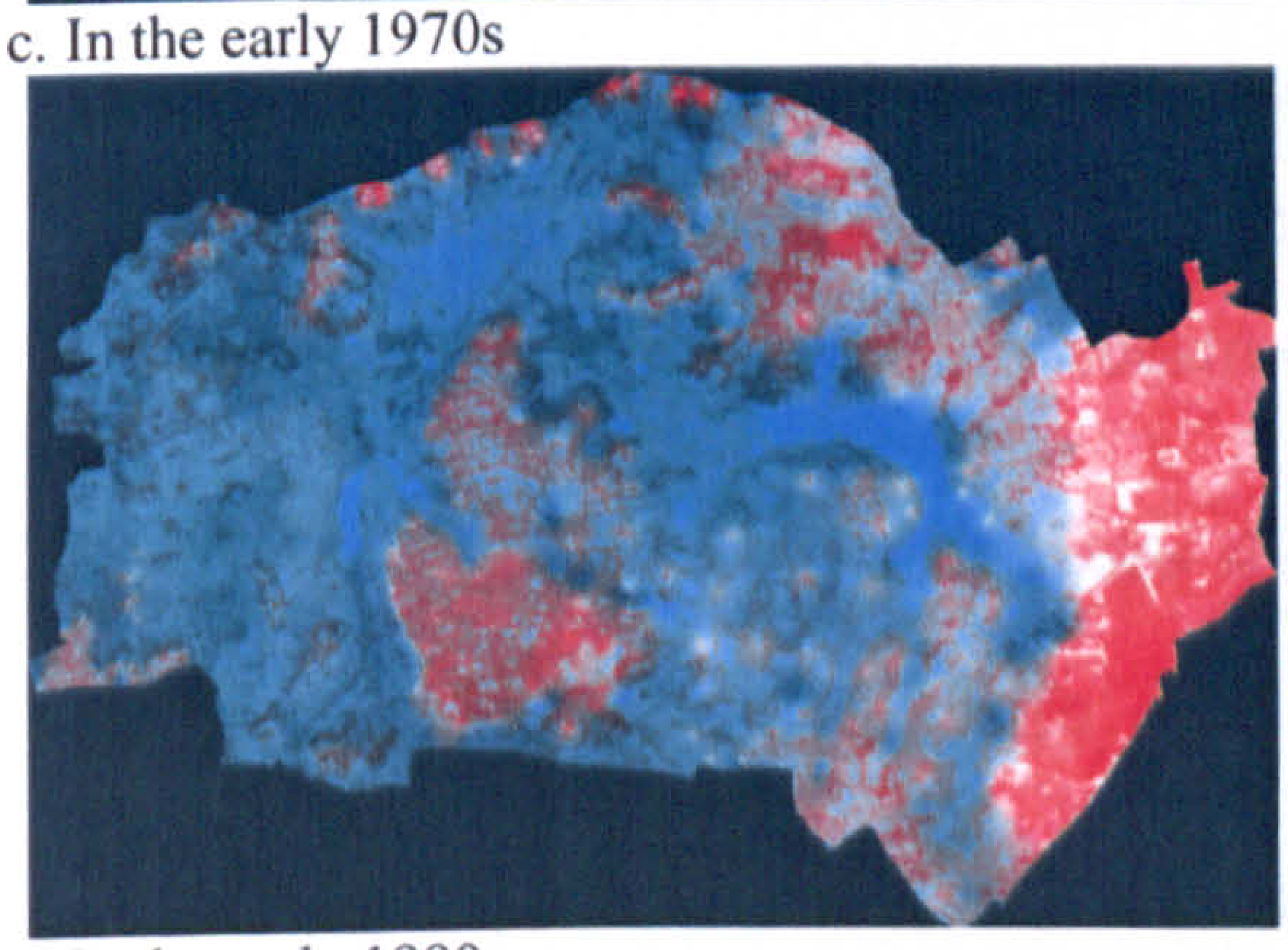
b. In the early 1960s



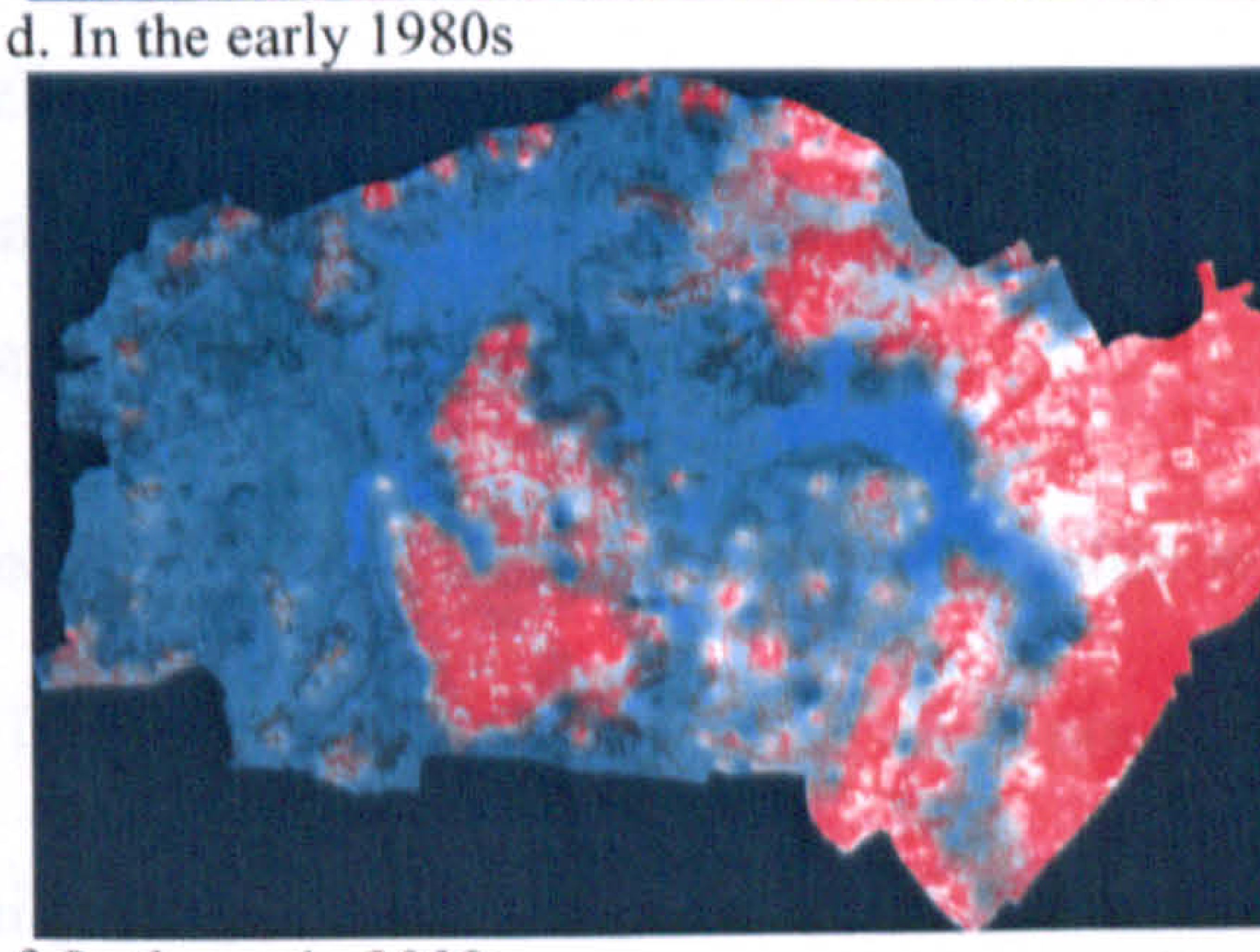
c. In the early 1970s



d. In the early 1980s

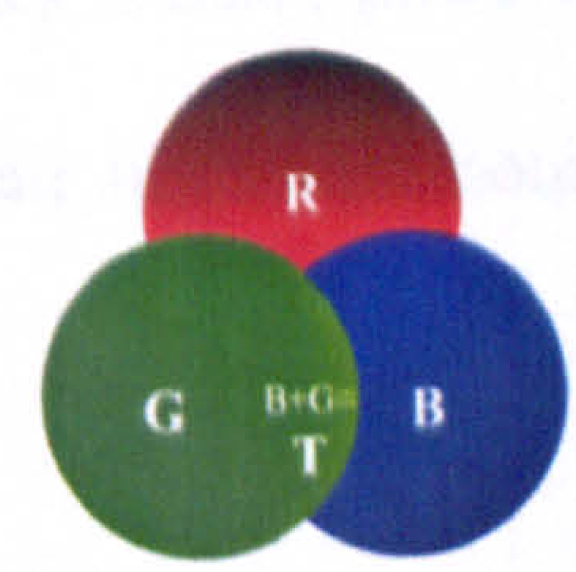


e. In the early 1990s



f. In the early 2000s

Figure 6-49: Adding (social) values to remote sensing as a band is given as a unique example of a land price transformation. Red (R) colour containing social data represents the higher land values while the turquoise colour (Green + Blue) containing spectral value reflects the physio-environmental context of the mauza in order to understand the complexity and importance of landmass and its dynamic influence on land value respatialisation at each date. (In the right diagram, I showed how the colour combinations work.



R = Land Value; and T = (G + B) = Panchromatic Image.

5. We can also add any field data-sets to the plot-attributes. This gives a unique opportunity for urban and rural planning and development. For example, if we add

the attributes of taxation of the land, and their relationship with the land types, then it can also give a clear idea of the interaction of the taxation process.

6. Any social factors responsible for land use change can also be monitored efficiently, for example, why is in-migration happening more in the eastern part than the western part of the study area in 2001. Why was it the opposite in 1951? What was the impact of the HYV revolution on land uses and land prices?
7. The advantage of overlay and buffering methods is that they help us to comprehend the complexity of the land in a micro-environment from plot (daag), paara (hamlet), to village (graam) to mauza levels.
8. The boundaries (*eyeels*), of the plots can help us to develop metadata and data of the individual plots from remotely sensed images.
9. The cost can be reduced of monitoring such rapidly changing mauzas, particularly those located on the outskirts of a city or of a growth centre and reduce the cost of intensive field survey every year.
10. The study of land values is also helpful to focus on prediction of where the land uses will change very soon. Higher land values indicate development and environmental status will change quickly in that area or region. For instance, the Jahangirnagar University Campus is changing quickly and land values in the early 1970s indicated that before any construction work had happened.

If we compare the earlier mauza maps showing land values with the land value and image data combined in Figure 6-49, there is no doubt that the meaning and context of the relatively expensive plots are more easily understood. Instead of thematic and dot maps, an integrated map of image-based socially weighted values is more powerful for decision-makers to interpret the current land use including their micro environments and land types.

6.6.3. Reasons for Spatial Distribution of Land Values

As we seen from the previous discussion and maps (e.g. Figure 6-38 and onward), the spatial distribution of land value data shows some interesting patterns. Maps of high land value plots have more importance than the lower prices. The maps give a glimpse of the plots of higher land values using various visual presentation techniques. For example in Figure 6-42 to 6-47, the dense concentrations of dots show the higher priced land at the time specified. There are several local factors responsible for the change. Maps of the land values for Bara Oalia Mauza over the last six decades show that the weight of the value is shifting spatially. Here, the total land value is considered as 100.000% so that we can overcome the inflation of local currency and ever-increased prices at decennial levels. Each dot represents 0.015% of the total land value in the given year. The factors are summarised in Table 6-13:

6.6.4. Weighing Temporal Influence of the Each Land Use Component

I have discussed the variety of land use and the immediate impact of land values in the context of spatio-temporal complexities. Moreover, the availability of high resolution single band remote sensing images has added a new dimension to the understanding of the land use sequence. Now we need to focus of the weight of the each land use category in the mauza, since that will also help to determine the factors responsible for changing the centre of gravity and centroid position and its development quadrants (the lines drawn from 25th and 75th percentiles). We need to determine which land values make the greater contribution in a particular geographic region. In this section, I will focus on that issue. Here, for illustrative purposes, I will analyse in detail only the 1951 and 2001 scenarios. These will help to understand the depth of the issues relevant to the land use pattern.

In the earlier sections, I discussed the land use of 1951, but now I will focus on the underlying values of land. Since we cannot allow only the total area of the land use in terms of Decimal or hectares to determine the weight of the particular category, I have added land value of each plot of the Bara Oalia mauza to show and assess the impact and the weight of the land use. In Tables 6-15 and 6-16, I have calculated the price of each land use component accordingly. Also these components are shown in Figures 6-

39 and 6-40. In Table 6-14, basic land uses are given with the number of plots involved, the total area in Decimal, and the price in taka in 1951 and 2001. In 1951, the contribution of the land use value of agricultural land was 51%, which is the most powerful of all the land uses and the reason for attracting the centroid to the western part of the mauza. If we consider land in 1951 that is still under the same category in 2001, the weight has been reduced to 36 percent of the mauza total. Water bodies and settlements represent the same amount of contribution at 18% each. But interestingly, the shaal forest region, which had only 8 percent in 1951, had (without trees) increased to 47 percent in 2001. The people who bought land in the lowlands in 1951 and sold their chala land in the east regretting misjudgement at that time. But those who were forced to leave the *beel* areas and suffered from no access to perennial water, are now the luckiest group by holding the most valuable land.

In Table 6-16, the land use pattern has changed considerably. More detailed and complex land use components have emerged. There has been a lot of structural change, with an agro-based society turning into a partly urbanised society. The overall weight has been changed dramatically for the each feature of land systems. For example, the land contributed only 4 percent in 1951 and is now about 28 percent. Due to this massive change in weight of the land, the centroid of the mauza has been completely reversed in comparison to the 1950s scenario. If we rank the components responsible for the central gravity reorientation, we can summarise it in the following way from the greater to the lesser influences.

Table 6-13: Basic reasons for changing land values and land transformation.

Decade	Zone of higher land price	Basic Reasons (based on mainly **Figure 6-49**)
1950s	Around the Oalia Lake located in north-west zone (Figure 6-42).	Surrounding chala settlements were highly dependent on perennial lakes, i.e. Oalia Beel as there was no alternative source of ground water all year at that time.
1960s	Entire western floodplain or *null-jomi* i.e. *chwak* (Figure 6-43).	Sudden improvements of HYV rice cultivation and irrigation facilities, and the western part is the most suitable for rice production due to floodable land. Most of the farmers at this time were focused on this land and the land was their prime source of income.
1970s	Both western and Eastern Ends of the mauza (Figure 6-44).	Suddenly, the establishment of Jahangirnagar University has played a role to shift the focus from the west to the east. At the same time agricultural activities in the east were also prominent.
1980s	Concentration of high land price focused in the eastern university part only (Figure 6-45).	At this time importance and influence of the university has expanded dramatically, and most of the weight of land was concentrated here. The impact of agriculture has started receding.
1990s	The university area has started merging with the central chalas (Figure 6-46).	Due to new in-migration in this mauza resulting from the location of the university, the entire western half got the special focus, so the weight of the university and villages started to coalesce.
2000s	The entire eastern half where the university and its neighbours are both located (Figure 6-47).	The focus on the western agricultural land has been completely lost, the chala lands got the maximum privileges, new villages on the adjacent of University emerging with new housing societies. Now the university shares its weight with its neighbours and has compromised its development with nearby villages. The central focus has started shifting towards the west again.

Sources: Map Interpretations 2002 and Field work 2001.

How and to what extent the land weight has changed can easily be monitored over time from examples. In 1951, agriculture had the highest ranking by showing its dominance over the others but in 2001 it had dropped into third place as agricultural activities could no longer play a sustainable role in the local economy. Infrastructure had the lowest status in 1951 but reached top most position in 2001 due to heavy development activities in the east. If we consider only the extent of the area without adding the land value as weight, this would provide a very unrealistic picture of the above land use ranking. It can be predicted, as already seen in Dhaka city, that in a few decades most of the land will be part of infrastructural developments, and may carry more than 90 percent weight. In this time frame, agricultural activities may collapse totally due to the rapid urban expansion.

Table 6-14: Weighted Land Use Ranking for Dispersing Centroid in 1951 and 2001

Rank	Weighted Land Use Context in 1951	Weighted Land Use Context in 2001
1- Top	Agriculture: 51%	Infrastructures (incl. JU): 40 %
2	Water Bodies: 19%	Household Land: 34%
3	Household land: 18%	Agriculture: 23 %
4	Forestry: 8%	Roads: 2%
5	Roads: 3%	Water Bodies: 1%
6 - Bottom	Infrastructure: 1%	Forestry (disappeared): 0%

Source: Data summarised from Tables 6-15 and 6-16

Therefore, from the above examples, we can gauge the specific factors responsible for changing land features. Both social and image data can play a role in this regard. The influence of categories (e.g. water bodies) and subcategories (e.g. *khal, beel* and *pukurs*) can also be identified very clearly. The land-weight method can help in the development and planning sectors in Bangladesh for the decision makers. It also helps to identify the development disparity in a geographic region. So a planner or decision-maker can focus on the deprived zone specifically and the perceptions of local people analysed. The remote sensing data sets give us the detailed land use picture of the past and the land value data of the same area gives us the weight of the major components.

Table 6-15: Basic statistics of land use of 1951 and their corresponding land price in 1951 and 2001

LAND USE 1951	No of RS Plots	Area in Decimal	Price in 1951 in Taka	Price in 2001 in Taka**	Price in 1951 in %	Price Weight in 2001 in %**	Major Price Weight in 1951**	Major Price Weight in 2001*
Agri : Fallow Byde Land	78	6069	13133	190105810	4.913	5.639	51.096 %	36.143 %
Agri : Grazing Land	82	5640	10908	177843020	4.079	5.276		
Agri : Jackfruit Orchards	76	7460	16524	330323860	6.179	9.798		
Agri : Rainfed Crops	462	12919	35630	134775480	13.317	4.002		
Agri : Rabi Crops	68	1481	3905	32280080	1.463	0.959		
Agri: Boro / Rabi Crops	225	14356	56568	352869620	21.145	10.469		
Forest: Shaal Baan or Shrubs	113	21933	21935	1574001560	8.203	46.709	8.203 %	46.709 %
HH : Bari with Veg/Orchard	178	8062	48863	425021780	18.269	12.611	18.269 %	12.611 %
Infra : Religion / Mosque	3	101	913	3482050	0.342	0.104	0.987 %	0.448 %
Infra : Tong Ghar & Shop	2	255	1724	11612250	0.645	0.344		
RD : Halot & Katcha Road	41	1391	6952	81347355	2.597	2.415	2.597 %	2.415 %
WB : Khal /Canal	1	201	100	100340	0.058	0.018	18.848 %	1.674 %
WB : Perennial Water	216	12228	49379	54054005	18.458	1.601		
WB : Pukur / Ponds	2	117	888	1857275	0.332	0.055		
Total of Bara Oalia Mauza	**1,547**	**92,212**	**267,422**	**3,369,674,485**	**100.000**	**100.000**	**100.000 %**	100.000 %

Source: Land records and Field data, 2001 (** marked columns are for information only to see the same land feature priced in the 2001)

Table 6-16: **Basic statistics of land use of 2001 and their corresponding land price in 1951 and 2001**

LAND USE 2001	**No of RS Plots**	**Area in Decimal**	Price in 1951 in Taka**	**Price in 2001 in Taka**	Price Weight in 1951 in %**	**Price Weight in 2001 in %**	Major Price Weight in 1951**	**Major Price Weight in 2001**
Agri : All 3 Seasons	392	17785	26773	508919160	10.037	15.094		
Agri : Prak-kharif & Rabi	277	9454	26888	90419840	10.053	2.688		
Agri: Boro / Rabi Crops	355	19939	100186	109636420	37.455	3.249	58.175 %	**23.138 %**
Agri : Bamboo Jhar & Ghar	12	1194	1589	69851500	0.594	2.071		
Agri : Deep Tube well	1	24	96	717300	0.036	0.036		
HH : Bari with Veg/Orchard	292	19702	70415	1092855720	26.323	32.431	26.730 %	**34.044 %**
HH : Proposed Housing Society	2	1088	1088	54377500	0.407	1.613		
Infra : Box Culvert / Small Bridge	6	585	714	31343035	0.266	0.929		
Infra : Generator House	1	559	559	39155200	0.209	1.162		
Infra : KG School	1	676	676	47310900	0.253	1.404		
Infra : NGO Offices	4	288	797	11564200	0.298	0.343	5.592 %	**10.546 %**
Infra : Poultry Farm	5	620	1330	35411100	0.496	1.051		
Infra : Religion / Mosque	14	1702	4066	103490550	1.522	3.072		
Infra : Tong Ghars & Shops	9	2195	6813	87106280	2.548	2.585		
JU : Admin & Halls	1	594	594	59364000	0.222	1.762		
JU : Faculty & Hall	1	1489	1489	148935000	0.557	4.420		
JU : High School	10	651	920	56719360	0.343	1.683		
JU : Lakes & Ponds	23	2455	4142	213886300	1.548	6.346	4.468 %	**29.400 %**
JU : Lease for Agri	11	788	787	70958700	0.294	2.105		
JU : Staff Residence	3	295	295	20128120	0.111	0.598		
JU : Expansion Underway	29	4207	4207	420733000	1.573	12.486		
RD : Halot & Katcha Road	41	1391	6952	81347355	2.597	2.415	2.597 %	**2.415 %**
WB : Khal / Canal	1	201	100	100340	0.037	0.003		
WB : Perennial Water /Beels	49	4008	3953	7716170	1.476	0.228	2.258 %	**0.457 %**
WB : Pukur / Ponds	7	321	1993	7627435	0.745	0.226		
Total of Bara Oalia Mauza	**1,547**	**92,212**	**267,422**	**3,369,674,485**	**100.000**	**100.000**	100.000 %	**100.000 %**

Source: Land records and Field data, 2001 (** marked columns are for information only to see the same land feature priced in the 1951)

6.7.0. Conclusion

In this chapter we have seen the relation between high resolution remote sensing images and large scale mauza map for assessing the impact of land transformation, using social datasets such as land values. Very high-resolution satellite data can effectively help for monitoring change of the land and people can take part more if we can use mauza maps guided by imagery like CORONA. It is helpful to take a group of ordinary people from every mauza including key informants, who have extensive knowledge about the plot level mauza maps, so that they can participate in the planning processes. Moreover, existing plans can be reviewed and coordinated in the light of their skilled knowledge and familiarity with the land. Environmental sustainability is best achieved if local villagers are involved in the process of land transformation and planning instead of development of land being solely in the hands of developers with their own agenda.

After issues involving the participatory method, I focused on land use and land values where both the general and weighted land systems have been illustrated. Also, land values in a free market economy and without any control of the government decide the outcome of many complex land development of the past, present or future. They reflect so many local and regional factors in numeric form. I have also focused on how we can integrate land values in the understanding of the dynamics of land use and land cover change over time. Though I focused on only one village, these methods could be used for larger perspectives, for instance, at the upazila or district or even national level. Moreover, other social data can also be integrated using the same approaches. Using the weighting method, we can get a better perspective of factors responsible for any change.

By adding attributes with the help of mauza plot numbers, we have established that there are several factors responsible for the dynamics of the land. However, those relevant to the predevelopment society are not important for the recent pro-development society. For example, the low land was highly prized the agricultural based indigenous society but in the urbanisation phase it does not carry the same weight as urban settlement and should be on the flood-free *chala* land. Housing is now more important than cultivation. The following factors are the most important to understand the phenomenal change of land values between predevelopment and developing context:

(1) Land types: relatively Lowland versus Highland;

(2) Floodibility: flood-prone versus flood-free;

(3) Agriculture: predevelopment versus developing contexts;

(4) Transportation: communication network though water (boat) versus road (automobiles);

(5) Growth Centre: Hat-bazaar versus Open Spaces;

(6) Settlement Expansion: margins of overcrowded populated areas versus neglected chala land.

From the consumer price index, we know the deflation rate of the currency, but the rapid increase of land values is also a very significant indication of the influence of land values in the local land use pattern and monitoring, including weight dispersion and centroids. Moreover, local people also mentioned that before changing the landscape physically, the land values change first, which gives a forecast of future land potential.

The mauza maps used in the chapter date from the early 1970s when the CORONA satellite image was captured. We have monitored various aspects of the land use using these CORONA images. Interestingly, both the mauza map and CORONA image have approximately the same resolution or scale. For the land use components, we can see that major changes occurred between 1951 and 2001. Among these, deforestation and the establishment of Jahangirnagar University are the most important.

The significance of this chapter is that we have investigated the land use with the weight factor of land values. This helps us to see the focus of the land and how the situation and the centroid have changed from 1951 to 2001. The influence of the *beel* had initially kept this centroid to the west, while infrastructural developments later reversed the situation, that is from the west to the east. The maximum gravity of the HYV rice cultivation in the predevelopment phase played a role in making the centre of gravity 540 metres from the reference centroid but in 1991 the development of the university pulled this centroid about 829 metres from its position in 1981. This specific example helps to quantify the weight of the particular feature of the land.

Finally, I have mapped the high resolution remotely sensed data for the interpretation of the numeric values of the weighted land use. Without integrating the images with the land value data, it would have been very difficult to explain the historical spatio-temporal distribution of a land use pattern and its evolution. This integrated image gave us a new dimension of understanding a land. With the help of a time series images, the overall context and pattern of change can be identified efficiently. The chapter has shown how data from the field can be combined with the space-borne photography to understand the impact of land transformation in a way which has not been explored before in Bangladesh.

Table 6-17: Generalised agricultural practices including some remarkable fruits and perennial trees of Oalia *Mauza* by land types and seasonal crop calendar at decennial scale over the last 50 years.

CROPS and FRUITS		Suitability by Land Types	LAND TYPES					SEASONS			DECADAL SHIFT					
			Highland	Medium Highland	Medium Lowland	Low land	Very Lowland	Prak-Kharif (Mar-May)	Kharif (June-October)	Rabi (November- Feb)	Early 1950s	Early 1960s	Early 1970s	Early 1980s	Early 1990s	Early 2000s
Jute *(Paat)*	*Tosha (Veli)*	S	X								N	F	F	F	O	N
		M		X												
		U			X	X	X									
	Deshi (Guti)	S	X	X	X						F	F	F	F	O	O
		M														
		U				X	X									
Wheat *(Gaam)*	Irrigated	S	X	X	X						N	N	N	O	O	O
		M				X					N	N	N	O	O	O
		U					X									
	Unirrigated	S	X	X	X						N	N	N	N	O	O
		M				X					N	N	N	O	O	O
		U					X									
Mustard *(Shorisha)*	HYV (Rape Seed) Irrigated	S	X	X	X						N	N	O	F	F	F
		M				X					N	N	O	O	O	O
		U					X									
	Local Unirrigated	S	X	X	X						N	O	O	N	N	N
		M				X					O	O	O	O	N	N
		U					X									
Potato	Irrigated	S	X	X	X						O	O	F	F	F	F
		M				X					N	N	N	N	N	O
		U					X									
Barley *(Job)*	Irrigated	S	X	X	X						F	O	O	N	N	N
		M				X					F	O	O	O	N	N
		U					X									
Maize *(Bhut'ta)*	Irrigated	S	X	X	X						N	N	N	O	O	N
		M				X					N	N	N	O	O	O
		U					X									
		S	X								N	O	O	N	N	N

CROPS and FRUITS		Suitability by Land Types	LAND TYPES					SEASONS			DECADAL SHIFT					
			Highland	Medium Highland	Medium Lowland	Low land	Very Lowland	Prak-Kharif (Mar-May)	Kharif (June-October)	Rabi (November- Feb)	Early 1950s	Early 1960s	Early 1970s	Early 1980s	Early 1990s	Early 2000s
	Kharif	M					X				N	O	O	O	O	O
	Unirrigated	U		X	X	X	X									
Gram		S	X	X	X						F	O	O	O	N	N
(Chholaa)	Unirrigated	M				X					O	O	O	O	O	O
		U					X									
Lentil		S	X	X							F	O	O	O	N	N
(Masur)	Unirrigated	M			X						O	O	O	O	O	O
		U				X	X									
Mung *(Moogh)*	Rabi	S	X	X							O	O	O	O	O	N
Beans(*Barbati*	Unirrigated	M			X						N	N	N	O	F	F
and Chheem)		U				X	X									
Black Gram	Rabi	S	X	X	X	X					F	F	O	O	N	N
(Mush Kaulai)	Unirrigated	M														
		U					X									
Sunflower		S	X	X							O	O	O	N	N	N
(Surjomukhi)	Unirrigated	M			X						N	N	O	O	O	O
		U				X	X									
Groundnut	Rabi	S	X	X	X						O	O	O	N	N	N
(Cheena	Unirrigated	M														
Baadam)		U				X	X									
	Kharif	S	X								N	N	N	O	O	O
	Unirrigated	M														
		U		X	X	X	X									
Cauliflower/		S	X	X							N	N	N	O	F	F
Cabbage(*Fool/*	Irrigated	M			X						N	N	O	F	F	F
Badha Kopi)		U				X	X									
Tomato	Rabi	S	X	X							N	N	F	F	F	O
(Tomato)	Irrigated	M			X						O	O	F	F	F	F
		U				X	X									
Brinja(*Begoon*	Rabi	S	X	X							N	N	F	F	F	O

CROPS and FRUITS		Suitability by Land Types	Highland	Medium Highland	Medium Lowland	Low land	Very Lowland	Prak-Kharif (Mar-May)	Kharif (June-October)	Rabi (November- Feb)	Early 1950s	Early 1960s	Early 1970s	Early 1980s	Early 1990s	Early 2000s
			LAND TYPES					SEASONS			DECADAL SHIFT					
/Aubergine)	Irrigated	M														
Okra*(Dharos)*		U			X	X	X									
Spinach / *(Palong-sak)*	*Lalsak* (Indian Spinach) Irrigated	S	X	X							O	O	O	O	O	O
		M			X						O	O	O	O	O	O
		U				X	X									
Chilli *(Morich)*	Rabi Irrigated	S	X	X							O	O	O	O	O	O
		M			X						N	N	N	N	O	O
		U				X	X									
Pumpkin *(Koomra)*		S		X							O	O	O	O	O	O
		M	X								N	N	N	N	O	O
		U			X	X	X									
Palwal *(Patal)*	Kharif	S	X								O	O	O	O	N	N
		M		X							N	N	N	O	O	O
		U			X	X	X									
Radish/*Moola* Turnip/*Shalgom*Carrot/*Gajor*	Irrigated	S	X								O	O	O	O	O	O
		M														
		U		X	X	X	X									
Bitter-/Snake-/Ribbed-/Teasel- Gourd	Unirr.*(Karala Chichinga, Jhinga, Kakrol)*	S	X								O	O	F	F	O	O
		M														
		U		X	X	X	X									
Onion *(Peeaj)* Garlic (*Rasoon)*	Irrigated	S	X	X							N	N	O	O	O	O
		M			X							O	O	O	N	N
		U				X	X									
Ginger*(Aada)* Turmeric *(Halood)*	Unirrigated	S	X								O	O	O	O	O	O
		M														
		U		X	X	X	X									
Betel *(Paan)*	Unirrigated	S	X								N	N	N	O	N	N
		M														
		U		X	X	X	X									
Sugarcane	Irrigated	S	X								N	N	O	F	O	N

CROPS and FRUITS		Suitability by Land Types	LAND TYPES: Highland	Medium Highland	Medium Lowland	Low land	Very Lowland	SEASONS: Prak-Kharif (Mar-May)	Kharif (June-October)	Rabi (November- Feb)	DECADAL SHIFT: Early 1950s	Early 1960s	Early 1970s	Early 1980s	Early 1990s	Early 2000s
(Aakh)		M		X							N	N	O	F	O	O
		U			X	X	X									
Banana *(Kaula)*	Irrigated	S	X								O	O	O	O	O	O
		M														
		U		X	X	X	X									
Papaya *(Pay'pay)*	Occasionally Unirrigated	S	X								F	F	O	O	O	O
		M														
		U		X	X	X	X									
Pineapple *(Aanarash)* *Sazna*	Unirrigated	S	X								O	F	F	N	N	N
		M														
		U		X	X	X	X									
Water Melon *(Tarmuz)* Melon *(Khira/Futee/Bangi)*		S		X							O	O	O	O	O	O
		M	X								O	O	O	O	O	O
		U			X	X	X									
Local Arum/ Taro (Maan/ Mukhi Kachu)	Irrigated	S	X	X							O	O	O	O	O	O
		M														
		U			X	X	X									
Water Arum *(Pani Kachu)*	Unirrigated	S	X								N	N	N	O	O	O
		M		X	X						N	N	N	N	N	O
		U				X	X									
Cotton *(Toola)*	Rabi Irrigated	S	X								N	N	O	O	N	N
		M														
		U		X	X	X	X									
Lemon *(Lebu)* Peogeon Pea or Red Gram (*Arahar)*		S	X								F	F	F	F	O	O
		M		X												
		U			X	X	X									
Mango Fruit *(Aamm)*		S	X								O	F	F	O	O	O
		M		X							O	O	F	F	O	O
		U			X	X	X									
Jack Fruit		S	X								F	F	F	F	O	O

CROPS and FRUITS	Suitability by Land Types	LAND TYPES					SEASONS			DECADAL SHIFT					
		Highland	Medium Highland	Medium Lowland	Low land	Very Lowland	Prak-Kharif (Mar-May)	Kharif (June-October)	Rabi (November- Feb)	Early 1950s	Early 1960s	Early 1970s	Early 1980s	Early 1990s	Early 2000s
(Kathal)	M														
	U		X	X	X	X									
Coconut *(Naarikel)* Betel nut *(Supaary)*	S	X								O	O	O	O	F	F
	M		X							O	O	O	O	O	O
	U			X	X	X									
Guava *(Peara)* Sapodilla *(Safeda)*	S	X								N	O	O	F	F	F
	M		X							O	O	O	O	O	O
	U			X	X	X									
Palm Tree *(Taal* –for fruit, molasses/*gur* and juice*)*	S	X	X							F	F	F	O	O	N
	M														
	U			X	X	X									
Date palm *(Khejur'er Ras-for* juice and *gur)*	S	X								F	F	F	F	O	N
	M														
	U		X	X	X	X									
Mehgani (Timber/wood))	S	X	X							F	O	O	N	N	N
Shaal (Tick/Timber/wood))	M			X						F	N	N	N	N	N
Chhaan (For roof top)	U				X	X	X								

Chapter 7

Glossary, Bibliography and Appendix

CHAPTER 7: CONSPECTUS

7.1.0 Summary and Conclusions

This thesis has been an opportunity to evaluate how rural land use is gradually converted to urban using baseline historical data and remotely sensed images as witnesses. They have helped to identify the complex characteristics and context of the changes of land cover and land use. I selected an area where the land was changing faster than the average national level. The population factor (such as rapid growth rate) was one of the most important drivers and census reports helpfully gave the details of human population figures at decennial intervals. Remote sensing (RS) made a substantial contribution to the data context and physical nature of change, especially high resolution images, which showed the land features in detail parallel to the population census surveys.

Over the last 50 years several dimensions of transformation have been revealed using the first generation military satellite, CORONA KH cameras in the early 1960s and 1970s, a modern satellite, IRS-1D of 2000 for a pro-urban phase, and aerial photography from the early 1950s. These data covered in the predevelopment stage of the Upazila as well as the 1980s and 1990s during the developing phase, in parallel with published upazila census data from 1951 to 2001. The study was not only a demonstration of three distinctive historical perspectives, that is of the predevelopment, developing and urbanisation phases, but also an example of the integrated use of GIS and RS including pixelisation of social data (from a horizontal perspective, using field or door to door survey) with reflectance data (from a vertical perspective, from air or space). With the help of a detailed contextual background, I have made the non-image traditional GIS more transparent, meaningful and imageable. This work can also be used as a panorama of vector-raster combination based on large-scale mauza attributes for high-resolution imagery. I have made the following contributions in understanding of land transformations and discovering the role of a wide range of phenomena and of their complex interrelated systems.

(a) Data and Methodology

To analyse the census data, statistical software helped to evaluate trend analysis while image processing software helped to interpret image data. But to integrate both platforms using a common spatial analysis tool, I depended on a reliable system of software. In this situation, only Integrated Geographical Information Systems (IGIS) can play specific and substantial roles to make a bridge between them. Conventional maps needed to be transformed into a digital format to see both image and population data in a meaningful way. But sometimes poor quality secondary data and unexplored remote sensing data along with the technological skill of interpretation cannot explain everything without field experience of the study area. In my case fieldwork also played a very positive role in giving the micro-details and further context of the background history. To integrate field data and image data I applied a common geographic reference so that the image and map data could be in an integrated. Global Positioning Systems (GPS) gave a means to match them with significant accuracy. The following issues concerning data and methods are significant for this research.

Time Series Images: It was an exceptional opportunity, which was carefully planned, to use a time series of image at decennial intervals. I used six sets of images, one for each decade since the early 1950s. It was a rare opportunity to cover the 1950s to 2000 with high resolution panchromatic data. So at every stage of change on the land I was able to detect and interpret the context. This kind of study is also difficult to do without having the advanced means of storing and managing large amounts of digital data and the advanced capability of image processing techniques and GIS software.

Restriction Issues: This is a very promising side of my research that we can overcome the restriction issues involving data and images in Bangladesh. On the one hand, large scale mauza maps are not restricted in Bangladesh and are widely used for land registration purposes and anybody can buy them. Secondly, since IKONOS and subsequent satellites, one metre or submetre resolution satellite remote sensing data are also available globally to virtually anybody from authorised vendors (assuming the availability of funds) and, therefore, there is no longer a need to use restricted aerial photographs. Mauza map and high resolution imagery have high quality reputations and have a compatible scale and are complementary. By integrating them, non-image maps can be converted to an image-map and vice versa. For instance, mauza maps generally contain plot (daag) numbers, their extent and a list of owners, while CORONA images do not have that information. CORONA images contain land type, changeable water bodies, settlement locations, vegetation cover and so on. If we combine the plots and their attributes with CORONA images, then together they become a very powerful tool for decision-makers, local government, planners, developers, lawyers, environmentalists and (both social and physical) researchers. We should not miss this new window of opportunity and can to some extent by pass the red taped bureaucratic system of Bangladesh.

Integrated GIS Platform: The integrated GIS approach was the basis of the entire study, to support the data and map them efficiently. All the data and maps presented in the research were the outcome of the GIS capabilities. For example, data entry, topology building, map digitisation, image integration, overlapping, buffering, geo-processing, projection, attribute data development, and intersecting of various polygons, and line and point coverages were the basic functions of the system. The current GIS system can handle both raster and vector data and this was an additional advantage.

Unexplored Potential of CORONA: The very high resolution, cheaply available CORONA is still unknown to Bangladeshi researchers, private and government communities. This research will help to encourage them to use this valuable data for the development and planning of Bangladesh. Very rich mauza data will also play a significant role for developing baseline information of Bangladesh for the post-independence period. Moreover, Bangladesh is a part of deltaic zone and the rivers are shifting so quickly, using both integrated CORONA and Mauza data, a detailed land management and monitoring system can be developed. Recent high resolution satellite images can be merged with the recent Bangladesh Survey (BS) mauza maps, which will also yield an understanding of the transformation from the rural to rural, rural to urban and urban to urban systems in detail, including changes of physiography and landscape though time.

Models Developed: The most useful techniques for studying and understanding the processes of transformation are: 1) high resolution remote sensing for contextualising transformation systems; 2) census data as population factors for change analysis and a jig-saw fit with remotely sensed data; 3) a spatio-temporal index for quantifying the land transformation; 4) integrated approaches using GIS and IAS for managing data handling; 5) pixelised social data for remote sensing images; 6) weighted land use and its dynamic centre of gravity for monitoring context; 7) participatory approaches for RS mapping with mauza data; 8) upazila maps (e.g. as census tracks) and mauza maps (e.g. as plot attributes) for developing base line information, environmental monitoring, sustainable planning and land managements; 9) ungeoreferenced census and mauza attributes to the georeferenced data using RS (for census mapping) and DGPS (for mauza mapping).

I can claim that the following methods and models have been developed from this research and on the basis of that we can draw a broader picture of transformation of the study area:

(1) Interpretation chart of imagery-based features and for each a reconstruction of their past with a contextualised transformation history;
(2) Enhanced (submauza) census mapping methods for mapping population census data;
(3) Introducing of a Spatio-temporal Transformation Index with parallel data and image;
(4) Effectiveness of a stepwise participatory remote sensing approach for adding value to high resolution 'plotted' images; and
(5) Use of pixelised social data as a spectral band of composite image with remote sensing data.

By-products of Research: In order to achieve the goals of this research, I have to maintain and to some extent introduce the new terms:

(1) **Quality Assessment:** During the research, I also raised issues about the quality of secondary data ranging from published population census data (e.g. population data of 1974) to printed maps by the LGED (e.g. Settlements Distribution) with the help of interpretation of RS images, DGPS Survey and detailed field-experience.
(2) **Geo-social Data:** I also highlighted, with practical examples, how we can use the above techniques effectively for understanding land transformation systems from physiographic feature specific phenomena (e.g. various land types) to the geo-social data (e.g. land value at plot level).
(3) **Use of Maps:** I also focused on several occasions on how medium scale maps (1:50,000) for development activities in Bangladesh can be used with GIS techniques

(e.g. school mapping) and how to use large scale maps for gravity of change monitoring the 'weighted land use' data (e.g. plot based mauza data), which may also suitable for detailed urban (or rural) area planning (1:3,960) for Bangladesh.

(4) **Data Types:** I have also used an integrated approach, where the census (e.g. population) and social data (e.g. land price), databases (e.g. list of mauza, area in km^2), datasets (e.g. population density using GIS), metadata (e.g. context of census data based on RS data), administrative units (e.g. upazila, union and mauza levels), and high resolution RS images (e.g. CORONA) were employed to understand and explain other sets of data. The DGPS technology have been successfully used to make them compatible and integrated.

(5) **Data Size:** The above data sets have not only been used for a single year or a particular decade. All of the data and images used were for understanding historical changes of micro-complexity from a predevelopment society to a developing to a pro-urban society between 1951 and 2001. This was a huge task and skill was involved with the handling of this multi-sourced, multi-format and multi-dated information. It was a great achievement to see not only for a particular year, but also the underlying history, the detailed spatio-temporal decennial dimensions from medium to large-scale systems.

(6) **Map Attributes:** The attributes of maps in GIS format are very easy to update. The socioeconomic and infrastructural development process is a very dynamic process and the nature of the relevant database changes very quickly. So through the GIS system we can update it and can help local government in the process. With the help of Remote Sensing, I have developed a very detailed spatio-historical database of Bara Oalia Mauza.

(7) **Nonimage versus Imageable Maps:** Plotted high resolution RS data is much more powerful than non-image maps in the GIS environment for a decision maker. It gives the full advantages of GIS capabilities for the RS data by combining both raster and vector data. For a rapidly changing area, this information system could play a significant role and even where the land-based surveying methods or field data collection may raise the question, in this area plotted RS images offer a tremendous opportunity. The databases developed with the high resolution images are more transparent and reliable.

Nongeoreferenced vs. Georeferenced Data: I have also revealed how non-georeferenced data (census data) and map (mauza maps) can be converted into a georeferenced form with the help of DGPS technology and their verification of the high resolution satellite images. Once the maps or data are georeferenced correctly, opportunities for the analyst open immediately. Before my field visit to Bangladesh, the declassification of higher accuracy GPS data by the Americans was most important news for the RS research and application communities, particularly for my study. I took full advantage of them during my field work and made the necessary geometric corrections and mosaicking accordingly based on them. Without them I could not have done at least two things: one, to enhance the population census data and the historical comparisons regarding settlement diffusion; two, plot the mauza maps on the CORONA, APs and remote sensing images. DGPS data has played a role of bridging between the maps and images and their overall integration in general. As we know from the Chapter 2, the CORONA images are originally available in film format. I was in the first group in the UK RS community who successfully converted them and made them compatible with other sources of data and images for doctoral research purposes.

Spatial Resolution: In this research, we have seen very high resolution data including remote sensing, census and mauza data. The resolution was ranging between 2-6 metres since the 1950s. The availability of high resolution data for every decade in a developing country is a very exceptional case. But this resolution helped me to see the micro details of the land and water bodies and helped me to interpret the image down to plot level. In the 1950s, the area was completely rural and there were no infrastructural presence, but I was able to see the settlements (for example) very clearly and the progress and change that has followed in the consecutive decades. Also visible was how the area became deforested and then other developments took place. Moreover, for the participatory RS mapping there was no other choice but to use high resolution RS (e.g. CORONA) data which the participants understood rather quickly.

(b) Assimilating Local Knowledge

The knowledge of remote sensing has been fully integrated with a very local and indigenous knowledge. For example, the chala, chwaks, kanda and so on have been verified from the land and a dichotomous key has been used to verify the local knowledge. Most interestingly, the broad classification of the land can also be classified from the satellite data very precisely with the help of this knowledge. For any topography, local insights are a must for understanding the context of a phenomenon surrounding it. From data to information to knowledge was one of the main focuses of the study. What, where, when and why were the principal questions in order to gain the proper epistemic context from the villagers.

(c) Integrated Approach

The study demonstrates the strength of an integrated approach and the phases of pragmatic understanding from data to information to epistemic based on temporal and spatial successions. For example, I have used remote sensing images and the population census as prime source of data between 1951 and 2001. Then I have linked and converted them into information on land types and settlements and, finally, based on the field experience and additional information, I have interpreted them in order to see in map form, the centre of gravity change and the weights of the individual factors responsible for land transformation from a predevelopment society to pro-urban development dynamism.

(d) Multi-faced Transformation Systems

Multi-faced Transformation: Savar has faced 'multi-faced fundamental transformations' in the study period. These various stages of complex transformation processes during 1951-2001 shifted from a rural to an urban area; a predevelopment to an infrastructural-oriented society; from a riverward to a roadward economy; a lowland periphery to a high land territory; a temporal (e.g. inter-decennial) to a spatial (e.g. inter/intra-unions) transition; surface water reliance to ground water dependency; and diversified forestry environment to kathalisation to a monoculture agriculture system. These forms of change could not have been established without the detailed (in terms of resolution and scale) and dual (in terms of vertical and horizontal perspectives) understanding of land. The nature of these various types of transformation system would not have been exposed without the current research.

Broad Transformation Picture: It is better here to give a broad picture of the entire land transformation system rather than summarising each chapter. In Figure 7-1, I present a simplified version of the major and complex processes of land transformation under broad land categories since 1951. This will help to visualise the interrelated and interdependent phenomena and features and their sequence of change. For example, to see how virgin chala land became an urbanised area, we need to follow the distinctive blue arrowed lines on the figure. On the land type category, firstly we can select chala land; it has two categories: exterior and interior. Most of the chala interior was covered by dense shaal forest in the 1950s. This forested area was acquired by the government in the 1960s and they developed infrastructures like the University Campus. This was gradually expanded by the 1990s and played a role in urbanisation. I have given also a legend for understanding the various colour boxes in the diagram. These are: broad land types; major features of part of a land use or land cover; factors responsible for change; particular features that have reached a mature stage; degraded environmental phenomena; and interlinked or interdependent features in a temporal flow path between 1951 and 2001. Regarding environmental issues: brickfields, water pollution due to industrialisation, deforestation, ground water extraction, urban wastes, water logging and so on are the major concerns in the Upazila.

(e) Mauza Map Integration for Development Planning

Hundred year old mauza maps have surfaced through this research as an ally of high resolution satellite images. Bangladesh is rich in these maps and can plan a significant role for them in any detailed planning of land management. In order to match them with the remotely sensed images, we need only 4-8 ground coordinates of each mauza sheet and in my opinion the government should do this sort of survey as soon as they can. Mauza maps in an integrated form with high resolution satellite images will help to face the challenges of the 21st century for all aspects from environment monitoring to land reform. In an integrated form, we will have geocoded (as every plots number has a unique identification ID) images (as every plots will be enriched with georeferenced RS images). The mauza maps are not restricted in Bangladesh and may play a significant part in solving several issues like monitoring change, environmental degradation, deforestation, river bank erosion, urbanisation, settlement pattern analysis and so on. In fact, the integrated mauza maps will open enormous application opportunities in Bangladesh.

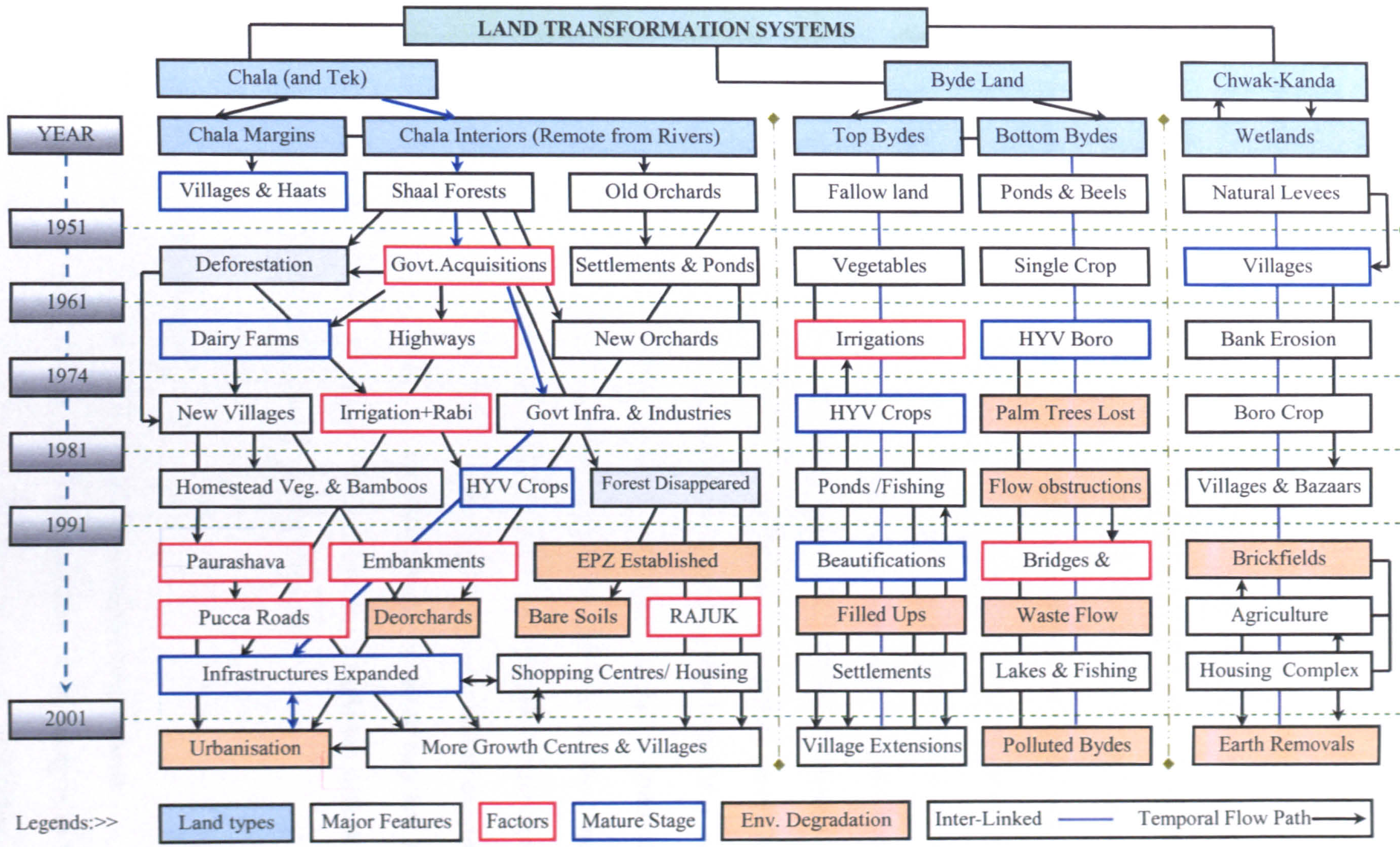


Figure 7-1: Generalised land transformation systems of Savar Upazila between 1951 and 2001. The changes in significant land features including factors are shown based on temporal scale. The blue arrowed line has explained in the text as an example.

(f) If I were do my PhD Again

I were to start my PhD again, I would rethink some of my steps. I would travel twice to the field, before and after analysing the data, but due to time and financial constraints, this was not possible. I would also look into the problem of lower resolution data, in which case I could resample the CORONA image to a 30-metre resolution and try to find out what sort of information could have been lost due to simplification compared with Landsat data. Then I would try to convert it into a global resolution (1 km or so) scale and ask 'does it mean anything'? We saw for the example of Bara Oalia Mauza that only a small compound village has a very diversified context and land use pattern. What would it show in two to four pixels due to simplification for a global study? Most probably, nothing. I would be more than satisfied if I could use the IKONOS 1-metre resolution panchromatic data (maybe with multi-spectral bands), but due to financial constraints, I could not use them. I have used the recent 5-metre IRS data and the 2-metre CORONA data, but I could not include the results in this thesis. In future, if I get opportunity to use IKONOS data, I will be pleased to analyse them. I have collected detailed data of four mauzas, but could only use them except Oalia mauza. In fact all together, I could not use two-thirds of my data in this thesis. But it is true that I could not forecast which sort of data would be helpful for analysis prior to my field visit.

(g) Weakness and Strength

At this stage, I should gauge the weakness and strength of the research.

Weakness of Secondary Data: The main weakness of the study is to use secondary published data. We often experience problems of data in developing countries like Bangladesh. For instance, when the data were from the secondary sources we found them mostly unreliable and unchecked, but with remotely sensing data we have successfully challenged the quality of the published census (both population and agriculture) data and map data. In this case, remote sensing is unbiased and a witness of the missing or misleading evidence. From all of the above achievements, as a by-product, I was able to make 'secondary data accountable' to the high resolution satellite data. For example: missing census data was identified at the mauza level; the misleading layout of road maps and settlement distributions have been highlighted; and common property plots (belonging to the river) distributed by corrupt surveyors have also been illustrated. Is it possible to detect these without remote sensing? The obvious answer is no. If it was possible, the datasets and maps would have been rectified in the mean time. These sorts of problems have been a part of the corrupt and/or inefficient systems of a poor country and ultimately the country has been misled and suffered for a prolonged period by losing information, monetary and physical resources.

Weakness of Secondary Maps: The quality of secondary data was also a weakness of the study. I can say for sure, that continuing non-use of high resolution remote sensing Data and the application of GIS will be a real problem for database development in developing countries. Through GIS, using overlapping techniques, we can easily identify the mismatching of datasets from various government sources. Sometimes it is very difficult to know which sources of secondary data are reliable. For example, the boundaries Savar Upazila drawn by the LGED (of local government ministry), SRDI (under agriculture ministry) and BBS (under planning ministry) are not the same. So I had to digitise the entire upazila from the Upazila root map titled 'Thana Map 1924'. All of the above organisations used it as base line source information. But due to map data handling by inexperienced people using crude techniques, the quality was degraded ultimately.

When I overlapped the map-data of primary schools of satellite images, some of them fall into beels and water bodies, so a DGPS survey was very important to locate them precisely on the image. If we look at the road map, no-one can understand what methods they have used to create it. It was just like a hand drawing. I talked to the LGED and they acknowledged the problem verbally and requested me to provide my data after completion of my research so that they could update their data and maps. In fact, high resolution satellite images made all of the secondary data and maps accountable. These images are highly valuable for any type of study. Before professional planning can start in Bangladesh, we need quality and reliable data sources, because no plan can be sustained based on misleading secondary information. In the thesis, we saw that a lot of mauzas were not surveyed at all for the census. So how can we get the accurate population future of Bangladesh? The data we rely on are of very poor quality.

Night-time Image: After the massive progress in acquiring and handling large sets of satellite data and information, still there is a lack of understanding of context. For example, a significant number of current authors including Doll *et al* (2000) and Elvidge *et al* (2001) have argued for global mapping of settlements or built-up areas using night-time images. From the night-time image outputs, the Indian Subcontinent including Bangladesh, for instance, does not show the expected presence of settlements for one billion people because electric light is not affordable for many people in poor countries.

(1) In Savar, there are no street lights despite there being a large population here as well as a very important national highway.
(2) On a regular basis, one part (say 25 percent of the entire Upazila) goes under 'load sharing' of electricity at every night for several hours, and any picture taken by satellite at that time would be unrepresentative. Due to chronic shortages of power supply in the peak hours the availability of electricity is a serious problem. Sometimes

to provide extra power supply to the EPZ and the Cantonment, the rest of the Upazila goes without power.

(3) Most of the tin-roofed houses are covered by homestead tree canopies to protect from them vertical sunlight in the summer, so the light source of these houses is difficult to anyway monitor. Moreover, people only use a few bulbs within the bedrooms of their houses and no light shines outside the home.

Small vs. Large Scale Study: Woolman and Fournier (1987) argued that a historical perspective is essential in considering land transformation and agriculture as it provides the best possible illustration of a way in which land is transformed, both spatially and qualitatively. Population pressure, conflict, technological revolutions and a variety of social changes throughout history have resulted in profound transformation of the land. According to their opinion, history provides good examples of continuing change, changes mirroring those of today and those certain to occur in the future. But their main focus was on agriculture and they used the continental or country-scale as case studies. Due to lack of detailed data (e.g. plot data), advanced means of handling (e.g. GIS) and the unavailability of high resolution images (e.g. CORONA or IRS) to the research community at that time, they could not study on a large scale the detailed complexity and context of the land. In this research I have overcome these issues by following an integrated approach and strengthened the foundation of my research.

Importance of CORONA: One of the major strengths of this research is the use of high resolution satellite images, particularly the relatively unexplored CORONA reconnaissance images. The declassified high resolution satellite does not only contain the picture of a day in the past also reflects a history of the otherwise unknown. In my research the CORONA was a milestone for most explanations. I can cite a few examples:

(1) It helped to understand the change of the physiography of the past;

(2) It gave the old settlement pattern in comparison with the current images;

(3) It also worked as past evidence of the vegetation cover and forestry resources;

(4) It yielded invaluable evidence of archaeological sites in Savar not seen before;

(5) It guided the explanation of the mauza plot maps (revenues survey) of Savar;

(6) It helped to verify and challenge the quality of population census data successfully;

(7) It gave a history of the past road and river networks;

(8) It helped to understand the land by Participatory Remote Sensing due to its photo-quality images;

(9) The image has enough resolution to add social data to understand its context;

(10) It could be used as a base line information image source compatible with any current or future high resolution satellite data.

For understanding land transformation, CORONA has never been verified in so many ways before. As in Bangladesh aerial photos are restricted, CORONA can be a very good and cheap alternative source of information.

Multidisciplinary Approach: If I want to point out the weakness of my research, the main problem is that the data are so diversified (e.g. from a household level to a satellite sensor, from today to a half a century ago) and it is very difficult to manage data covering such a vast multidisciplinary field which also requires an intensive knowledge and background on the study site. It needs an understanding of both remote sensing and social science simultaneously. To conduct any pioneering research in a multi-disciplinary field, it is not easy to meld them together in an integrated form. Also, it requires great skill and proper training to handle and manage data from various sources, and there is always a risk in undertaking an ambitious project for a degree, the data can lead in so many directions and it is sometimes very difficult to find the right path of study.

7.2.0 Evaluation of Objectives

To achieve my primary aim, I chose 5 objectives to implement. Now I need to evaluate these objectives one by one as given below:

Objective (a) *To collect and develop data and images of land transformation systems*

Objective (a) was the most difficult and challenging part of the thesis before starting my PhD due to several reasons, especially whether I could get the high resolution remote sensing images in parallel to the decennial census datasets between 1951 and 2001. By coincidence, I got the declassified CORONA of the 1962 and 1972, which helped to fulfil this objective. From a negative film, I used a high quality photogrammetric scanner and was able to convert the image into a digital format. I also acquired Aerial Photos of the early 1950s, 1980s and 1990s and perfectly matched them both with CORONA and parallel census data despite the tight controls on use in Bangladesh. I also successfully used IRS-1D Pan Satellite images, which has only been used hitherto to a limited extent in the west for land transformation studies with other compatible imageries. I did not just collect the series of RS data for each decade, but had to make sure that all of them were for the dry season, otherwise under the flood water, some land features like channels, khals, bydes, brickfields, lowland plots would have been distorted or invisible.

For the census data, I used published sources, from 1951 to 1991 but for 2001 I had to plan carefully to visit Bangladesh during the population census survey of that year. After persuading the field officers via various means, I obtained the unpublished census data of 2001 and this played a notable contribution in this research to make it up-to-date. At the same time, I collected plot level data for the micro-level analysis and had to carry out an intensive DGPS and field survey and ground truthing.

Finally, after having collected all the above datasets, I spent about a year to make them compatible in GIS format. It was a huge task but it was worth spending that time to get the appropriate results. Chapter 2 has highlighted various issues of dataset development and quality, including a brief outline of the study area and developed an approach of how to visualise the spatio-temporal scale of the land transformation system studies. The reader is referred to Figure 2-22, where all traditional and used data, maps and images are illustrated showing their resolution and scale simultaneously.

Bangladesh will benefit from this form of dataset development and results are guidelines not only for transformation study but also for local government, development planning and environmental monitoring. Most of the data available have been developed independently and normally there is no opportunity to overlap them using an integrated approach.

Objective (b) <u>To contextualise and interpret the process of land transformation</u>

Chapter 3 mainly focused on objective (b) and how to understand the land features using interpretation techniques. Here I added some additional parameters like season, sinuosity, history, human interference, sensor and edge, to the traditional elements of image interpretations methods. This was the first time that we saw the evolution of each feature between 1951 and 2001 and has reconstructed the history of past. Some of the findings were astonishing, for example, how a byde turned into a perennial lake; how a village has been completely destroyed with the shifting rivers and resurfaced again; and how a deghoir (lake) was created from a river.

With the application of a Dichotomous Key, I illustrated an example of land type features in my study area. Without knowing the local topography and context, the interpretation of an image may mislead. The chapter gave every detail of the prominent land, water, rural and urban, vegetation, road and industrial features, including the subcategories. Based on the findings of the chapter, I have developed local topographic interpretation charts which will be important in finding specific features and I also incorporated local Bangla terms and topographic names valuable for the entire Ganges and Brahmaputra Basin of Bangladesh and surrounding Indian part. It also emerged that a few metres height difference of the land can play a major role in determining the land use pattern. This chapter also demonstrate the 'spatio-historical images' of how the predevelopment landscape has changed to a developing and finally to a pro-urban society under various phases of development activities with a very complex context.

Objective (c) <u>To enhance population change data using interpretation of imagery</u>

For any transformation, population growth rate has been the most important influence for change. In Chapter 4, a link between census data and interpreted images was established although the census cannot give the context of the data, while remote sensing images cannot give the censual dimension of the data. The problem here was that the census data are not georeferenced and do not have the details of the settlement locations for each census tract. I have presented how to use Upazila maps at mauza level in order to enhance the population census data and how to integrate and classify them. No such of type work has been done elsewhere that I know of to use census and RS data in a complementary role. 'Enhancing the Resolution of Census Data' is a completely new term for academia. Table 4-4 shows a methodological framework of how to understand the context of population growth, and the method of enhancing census data resolution, and how to find out the missing census mauzas and factors responsible for overall transformation.

Bangladesh is the most densely populated country of the world. To properly plan population and human resources development there is no alternative but to use population census data in a meaningful manner. But, due to lack of georeference and settlement segments in the population statistics, high resolution remote sensing can come forward to map them accurately and efficiently. I have improved the spatial distribution of non-spatial census data by up to 86 percent (please see, for instance, Table 4-12 of Populated Area of Upazila and Figure 4-12), which is exceptionally helpful for the human resource development agencies, disaster management experts, planners and decision-makers in the region, including the whole Indian Subcontinent as all of them have shared the same sort of database since the colonial days. Also, for the first time the missing census data have been verified (Figure 4-21) and during the 2001 census survey experience, I explained the reasons behind the missing information in detail. Moreover, specifically for Savar Upazila, I have integrated population data into each image-derived settlement cluster and summarised the reasons of land transformation for each union in detail in Table 4-14.

Objective (d) To develop a spatio-temporal transformation index

It has never been tried before to quantify the rate of transformation. This method could be used as one of the milestones of the research. For this, I have developed a metadata for the integrated approach for calculating the change study base on the GIS topology and attributes in order to map the proportionate interdependent progress of certain phenomena and systems. For the Spatio-temporal (ST) index, I evaluated traditional population density and formulated new techniques for settlement density, occupied population density and adjusted population density of the study area. These methods helped to calculate the interdecennial change study with a key indicator for interpretation of the data (Table 5-6).

In practical in the studied area, I have illustrated an interesting visual method of looking at strength of the population at union level of various stages of development between 1951-2001 (Figure 5-4) in comparison to the adjusted ST index (Figure 5-14). The unions have been ranked to see the rate of change on land which will help to identify the disparity of the development process and help to justify the basis of resource allocation and development planning. The data have not only been quantified but also mapped (Figure 5-19) to see the change of settlement expansion during the last 5 decades. Based on the findings, I also applied the outcome (e.g., Figure 5-21) for planning needs and assessment.

Objective (e) <u>*To assess the social impact of land transformation at the plot level*</u>

I achieved the direct integration between a very large-scale 'revenue survey map' (1:3,960) with a similar resolution (about 2-metre) RS image for adding social data into the pixelised RS image. Chapter 6 covered general land use with the help of participatory RS mapping to a weighted land use with the help of land price data. With the help of state-of-the-art DGPS technology, I georeferenced the Mauza Map and detailed GIS attributes and database have been developed in this regard. A thorough field investigation and evidence have been presented in support of the RS and Mauza datasets. Most importantly, a weighted land use model has been suggested for understanding the gravity of change and the impact of various processes of development. The findings have been added as land values data with to RS image as a band, by pixelising social data. This pixelised method helps to contextualise the social data and strengthen the power of interpretation and knowledge of decision-making. Moreover, I used several visual spatio-temporal techniques and found that merging with the RS image gives an extraordinary performance for explaining the land cover data in respect of reasons for higher land price concentrations.

In terms of practical application in the region, the weighted method will guide us to find the underlying factors responsible for the overall changes and their specific influence in terms of percentages. For example, what is the influence of agricultural activities of the certain region for transforming land use? In 1951, it was 51 percent but in 2001 it is only 23 percent, despite a massive improvement in irrigation and yielding capacity. The university has changed the centre of gravity and reduced the weight of other factors. The weighted methods could be used with other applications as well like agricultural as population census data mapping and so on. Without the insight understanding of land, no planning and development process will be reliable.

7.3.0 Main Lessons from the Research: An Integrated Approach

We can now recap the memory of the research gaps section where a few examples have been cited in Figure 1-3. In this diagram I mainly wanted to demonstrate that several branches of change analysis have been developed but there is no integration of research models for land transformation system studies. The lack of integration yields only a partial picture rather than a complete scenario. In this case a multi disciplinary approach was essential, with a common platform where all of them can be utilised simultaneously. In this research, I have explained several aspects of the sources of data for change analysis and how they can work together without difficultiy. For example, census data have been surveyed for statistical purposes, CORONA data have been collected for military purposes, map data have been collected for revenue purposes and finally field data have been collected for understanding land features. In this research four different perspectives have been joined together for the study of land transformation. How to make the data truly integrated was the most important lesson of this research.

This research is based on a unique structure and organisation of decennial images and datasets for the last half century both from primary and secondary data sources at a very detailed and manageable scale. This work also uncovers the context of the landforms and their complex interrelations with the human population at the various stages of interdependency. The organisation of multi-shaped data and multi-sensoral images and establishing their chained-associations for understanding micro-systems of land transformation could not be achieved without having the proper application skills of advanced geographical information systems and image interpretation techniques and the taking the risk of handling several databases simultaneously. So the main lessons of the research are:

(a) Cadastral maps, remotely sensed images and social data can be integrated;

(b) High resolution satellites can add significant value to plot level social;

(c) Field experience can help to interpret unexplored data and can reconstruct the history of land use;

(d) It is possible to enhance population census data from mauza to submauza level and map them accurately;

(e) It is possible to quantify the rate of land transformation using census and remote sensing data;

(f) Old, underutilised large-scale maps can play a complement and enhance modern satellite data;

7.4.0 Future Direction of Land Transformation and Recommendations

(a) Relevant Aspects

Planning Need: A plan for an administrative unit, like an upazila, requires at least historical land use data and their context for understanding the process of transformation systems in order to achieve the goal of informed planning. In this regard, we need very detailed baseline reliable information for a meaningful planning programme, sustainable development, land resource management and so on. Throughout this research I have tried to develop that sort of database, and to understand their characteristics and applicability.

Justification of using High Resolution Imagery: This research can be considered as the basis of current and future research work on high resolution satellite data. Though the availability of high resolution satellites is a current phenomenon, with the help of CORONA and Aerial photos we can travel back more than 50 years. This is a significant contribution for future work in this area of research. Bangladesh is densely populated on a floodplain and always its appearance is changing rapidly seasonally, physically and infrastructurally from space, so spending was justified on high resolution data for mapping and monitoring purposes. The patterns of change have been mapped at the mauza scale, which would not have been possible without the aid of satellite images. If the price of high-resolution images falls, IKONOS and QuickBird (which have a better resolution than IRS) will create an even better opportunity for transformation studies and for mapping and planning the development purposes. In this case, CORONA could play a significant role, as it is the only satellite which has sufficient resolution to match them and can, therefore, be used as baseline information source. The biggest advantage of the CORONA data is that it is very cheap and holds the footprint of predevelopment scenarios.

Context First: Without knowing the seasonal variations and the micro-context of an area, we should not simplify the data for global research. In the case of a floodplain country like Bangladesh, an image from the dry season or the monsoon period would give different results in a change detection study. The land is so diversified and may change within a couple of weeks. Low spatial resolution data, such as that used for global research will result in simplification and loss of significant detail. The current use of RS data for global scale results may indeed mislead policy makers. We have to be very careful in this regard.

(b) Natural, Planned or Compromised Transformation?

We saw from my research that the process of transformation (1951-2001) in the upazila was mainly 'spontaneous and natural' for the ongoing change of land use and land cover rather part of a master plan. No-one is monitoring or evaluating this change and anyway there are no means to do so. Only a few cases like Jahangirnagar Campus or Export Processing Zone (EPZ) are controlled by proper government planning and funding but these sorts of land uses only cover less than 8 percent (22 km^2) of Savar Upazila. So 92 percent of the land has been going through an unplanned process of transformation until 2001. If we see the predevelopment scenario, 100 percent of the land was under the natural and ruralised phase and the pace of the change was very slow and traditional.

After having a Master Plan (1995-2015) from Rajuk, can we say still that change is natural or should it be treated as natural? Of course, the answer is no. The area is no longer in the predevelopment phase and, in the present 'take off' stage, we have a legal obligation to follow the Rajuk plan. The Upazila has a plan and guidelines for the first time in Savar's history. So what to do? In practice, even government officials are not aware of the Rajuk Master Plan (See Appendix A) and people are not used to it and asking them about the plan is impractical. So I can suggest several options:

(1) If we look at the ST (Spatio-temporal Transformation) Index in chapter 5, the recent trend of change is rapid and very difficult to control on the chala unions. The chala unions of SPZ 17-3 should be under full process of urbanisation and only the zone of the Turag basin should be restricted rather than the entire Union which also encompasses chala lands.

(2) The upazila administrations, local elected and local union parishads, should be involved in the planning and development system. In this case awareness programmes should be undertaken immediately on the Rajuk Master Plan at the SPZ and union level. Rajuk is supposed to evaluate its plan at 5 years intervals, so it should do this with the help of local government rather than just through its paper-dependent gazette notifications.

(3) Local people also have the right to see and comment on the plan, which has been neglected so far in Bangladesh. Some participatory approaches could be followed in this regard (Chapter 6). Villagers know their land better than the planners and they should be integrated with the planning process. And, for the monitoring, high resolution satellite images they can play a significant role.

'Planned transformation' should mean that land use cannot be changed without planning permission granted by the Rajuk Master Plan Authority. In Bangladesh planning is a matter of imposing edicts on the ordinary people whether they like it or not. Also, the government of Bangladesh has no resources to allocate or trained manpower to implement its red-taped planning systems. There is a scope here for protest by local people as seen in Figure 7-2 and such a chaotic system discourages Private Land Developers to build new cities without help of government or donor agency money. Donor agencies only give money to prepare a plan and after that they cannot monitor it and/or cannot fund its full implementations due to practical constraints. So these types of help are partly meaningless and encourage a corrupt system in the name of planning. Alternatively the donor agencies can help to develop base line information systems and fund (short, medium an long terms) for training skilled manpower, awareness programmes for locally elected bodies and officials, assistance to purchase satellite data, and mauza level plot data development. These could be treated as permanent resources for the country and will be helpful for a controlled transformation study and planning for any rapidly changing environment and contribute significantly to local government and NGOs for the benefit of ordinary people.

ঢাকা,মঙ্গলবার
০২ জুলাই ২০০২
১৮ আষাঢ় ১৪০৯
২০ রবিউল সানি ১৪২৩ হিজরি
রেজি: নং ডিএ ১৯২০
৩য় বর্ষ সংখ্যা ১৫৯

সত্যের সন্ধানে নির্ভীক THE DAILY JUGANTOR

যুগান্তর

টঙ্গী-আশুলিয়া সড়কে বিক্ষোভ : জীবন দেব তবু রাজউককে জমি দেব না

আশুলিয়ার নিউ উত্তরা মডেল টাউন প্রকল্পে মাটি ভরাট কাজে পুলিশের বাধার প্রতিবাদে স্থানীয় গ্রামবাসী প্রতিবাদ ও বিক্ষোভ মিছিল বের করে -যুগান্তর

সম্পাদক: গোলাম সারওয়ার

প্রকাশক সালমা ইসলাম কর্তৃক ১২/৭, উত্তর কমলাপুর (ইডেন মসজিদ সংলগ্ন) ঢাকা-১২১৭ থেকে প্রকাশিত এবং যমুনা প্রিন্টিং এন্ড পাবলিশিং থেকে মুদ্রিত। ফোন : পিএবিএক্স : ৮৮-০২-৭১০১৯৩৯, ৭১০১৯৪০, ৭১০২০০৪
রিপোর্টিং : ৮৮-০২-৭১০১৯৬৬ বিজ্ঞাপন : ৮৮-০২-৭১০১৩৮১ সার্কুলেশন : ৮৮-০২-৭১০১৯১৮ ফ্যাক্স : ৮৮-০২-৭১০১৯১৭

Source: www.jugantor.com on 2nd July 2002, Published in the Daily Jugantor.

Figure 7-2: A conflict between Rajuk and local villagers in SPZ 17-3 was a national headline news. The caption of the news was, "We will sacrifice our lives but will not handover our lands to Rajuk".

So, my overall view is to follow a 'compromise transformation' rather than 'fully planned transformation'. This compromise transformation will be based on people's opinions, consensus and market demand (including the participation of land developers and estate agencies like in Ashulia Model Town), which will be integrated by planners as a 'compromise form' of partial management approaches. Compromise transformation can be a bridge between the planner, decision-makers, local people and developers. In such a compromise plan, the preparation of road layouts and construction of roads would have the highest priority under government funding while other infrastructure will grow though the non-government involvements. Compromise transformation could be less costly and more practical for a poor country.

(c) Recommendations

It should be highly recommended, that any country like Bangladesh should store CORONA data in digital format for their national archive. For Savar upazila the past record has revealed its unwritten history. Remote sensing data can help to draw the historical sequence of land types. Involving key informants for monitoring and change analysis, it is a cheap and very effective means for planning and decision-making purposes.

We can monitor and update the population as well as agricultural census data for Bangladesh. The economy of Bangladesh is still based on primary economic activities, where remote sensing data can play a more significant role than for countries dependent on secondary or tertiary activities. The economy is especially dependent on the proper management of agricultural resources. After independence only twice (1984 and 1996) has a detailed agriculture census survey been conducted. As the cost of such survey is high, remote sensing technology can play a very significant role in this regard. Although this research did not discuss the data problems of agricultural census data, I found that there is a gross negligence in collecting and publishing the census data. For agricultural resource mapping and monitoring, high resolution data may work more efficiently. So policymakers should give priority to the use of remotely sensed data.

Due to the following reasons, the high resolution imagery should be used in Bangladesh:

(1) Bangladesh is the most densely populated country in the world and investment in RS is important to monitor land use change and transformation. If there is no quality data and maps as baseline information, we cannot produce a reliable and efficient planning system.

(2) The big cities of poor counties are developing urban ghettoes, and if we can have a good imagery based monitoring system, we could make significant progress on a healthy urban environment.

(3) Donor agencies are putting up a lot of money for development purposes, and they should encourage remote sensing data as part of their aid programme, as this is an impartial way of developing a country database.

I recommend some of the further issues which have been found as important for the academic arena:

(1) Detailed studies are needed to understand the context of global change research, because low resolution images may show areas close to Dhaka as rural;

(2) CORONA data should be used with the compatible high resolution satellite images both panchromatic and multi-spectral.

(3) The current study should continue for the next several decades to understand the full context from a complete rural to a complete urban area;

(4) The use of census data in the field of remote sensing has largely been ignored. This data could help to bring the social sciences and remote sensing fields together. Further research is needed to encourage both communities collectively.

(5) With the help of submetre DGPS technology, the traditional maps can be verified in developing countries and RS data can be an additional verification tool to update them. In developing countries the quality of data is a real problem.

(6) In the Indian Subcontinent, mauza maps are a unique contribution of the British colonial period, with the availability of census data, the maps could be easily upgraded and could be used as a base for further study.

(7) The techniques and approaches used for the census and field data in this thesis could verified in other parts of the world.

(8) In the case of regional and global change analysis, a lot of current studies are based on very low resolution datasets, but from this research I found that, even for high resolution satellite images, it was very difficult to analyse the data sets, and this required very good interpretation skills, so how can it be possible to do any meaningful change analysis at a larger scale. Data used for global change detection is highly generalised and might be misleading.

(9) A lot of Bangladesh organisations can get help from my research, including the LGED, Rajuk, Local Government institutions like Upazila or Union Parishads, NGOs, Bangladesh Bureau of Statistics, DLRS, Universities, and the Ministry of Environment.

(10) For the next population census survey, a detailed settlement and built-up area map should be prepared for the field-enumerators. It is very important to protect against the loss of valuable data and this will help to increase the quality of census data.

(d) 2031: Imaging Future Trend of Transformation?

Can we encapsulate a picture of future land transformation of the Upazila? It is projected that Savar will have the equal density of population of the current Dhaka city by 2031, or we can say that Dhaka city 30 years ago had the same density of population as Savar now. According to the Rajuk Master Plan, Savar will be an integrated part of Dhaka by 2015, and then it is assumed that density of population will increase dramatically. In this context, I took two image clips of Dhaka city and Savar which have a similar physiographic context for urbanisation and only a few km away from each other separated by the Turag basin. Through this example, we will be able to see the 2031 scenario of Savar in Figure 7-4 based on the current Picture of Figure 7-3. The current Dhaka city has grown without any plan and all development work has been done on an ad-hoc basis. We need a plan which will reflect of expectations of the *Savarbahsi* (people of Savar) through a compromise transformation policy. Otherwise the current Savar (Figure 7-3), full of vegetation cover and open spaces, will be overcrowded like Figure 7-4 within a couple of decades, without urban services and an adequate road network.

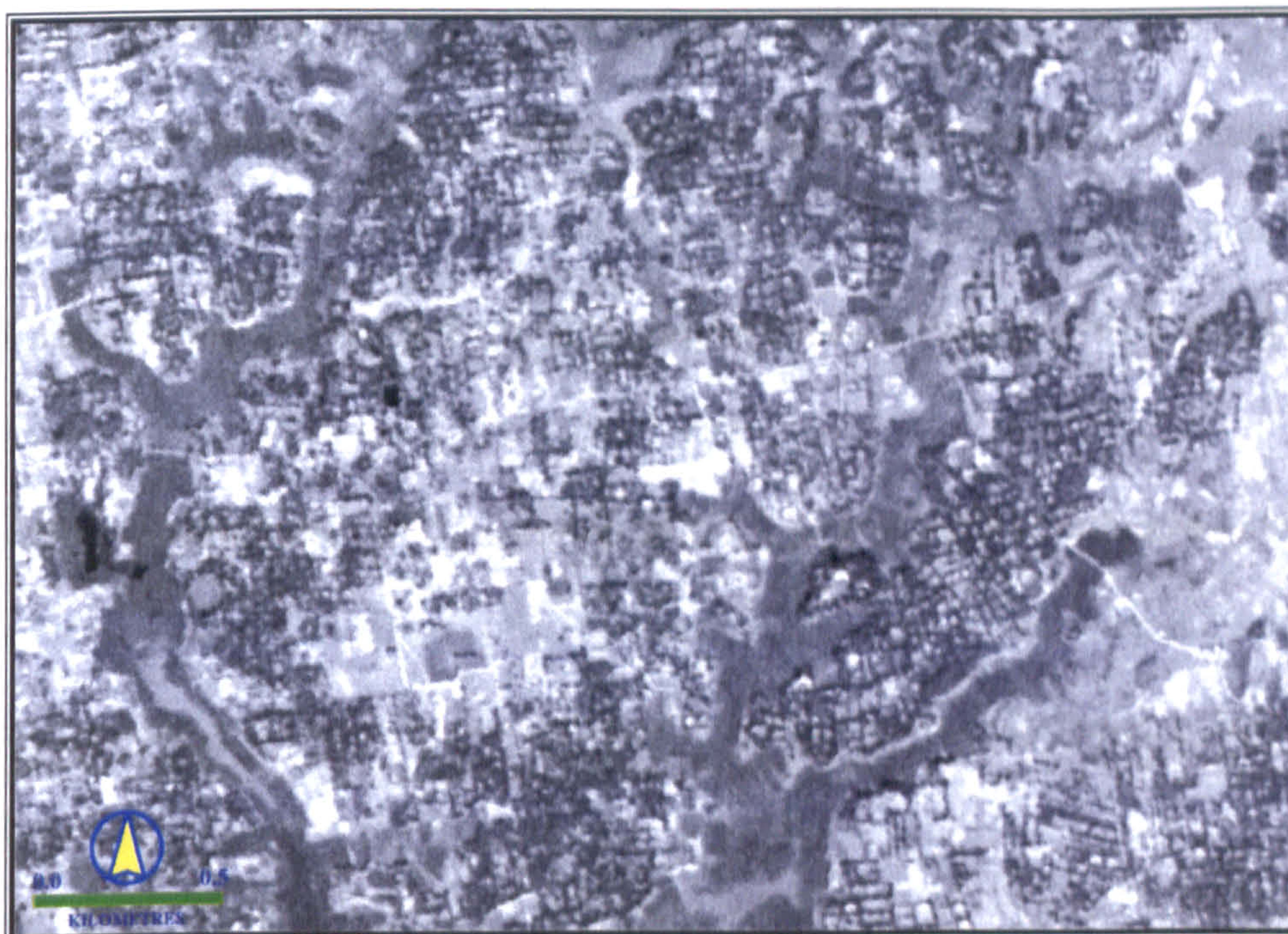
7.5.0 Geographic Perspectives of the Research

I could not conclude my work without one more vital and fundamental point. I will demonstrate whether this study fits with the recent approaches of geography's perspectives. The NRC[1] (1997) has highlighted how geography like other disciplines, has a well-developed, distinctive and coherent set of three perspectives through which the world can be analysed. These three dimensions are given below with a modified elaboration from my research:

(1) ***Geography's way of looking at the Upazila*** (horizontal axis or 1st dimension)

I have integrated social and physical data for the study of complex relationships among the transformation processes and phenomena. 'Interdependencies among places' give the relationships between unions or villages under the upazila or mauza respectively. Interdependencies among scales are one of the most significant contributions of this research as shown in Figure 2-22 in chapter 2.

[1] National Research Council of the USA for Rediscovering Geography: New Relevance for Science and Society.



Source: February 2000 IRS-1D , 2002

Figure 7-3: This is the typical current land cover situation of Savar where trees and byde are still prominent with rural features. Virtually all rural settlements have homestead forests and nearby open spaces. Only a few km away Dhaka City has the opposite picture. Both of the images contain the same context such as scale and underlying land type. The images are only 2 km away from each other across the river Turag.

Source: February 2000 IRS-1D, 2002

Figure 7-4: This is an imaginable scenario (taken from nearby capital city) for Savar in a few decades, where Savar will be an integrated part of highly populated and concrete-like rapidly expanding Dhaka. Here the density of population is at least 30-50 times higher than the image above. There are no signs of bydes (lost due to being filled-up) or vegetation cover (lost due to massive and unplanned constructions). And there is not a sufficient road network to get access in the individual houses or buildings.

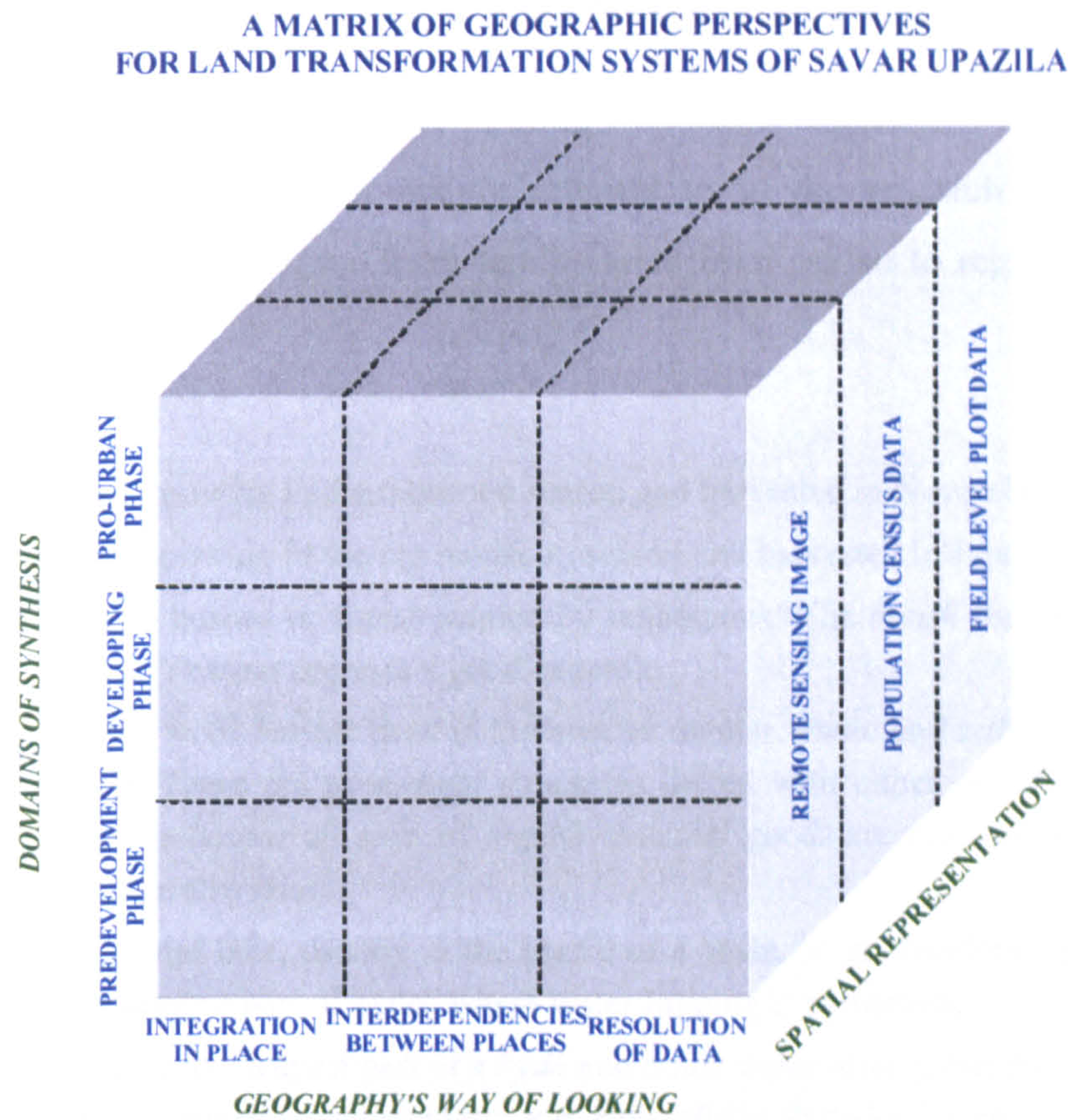
(2) *Geography's domains of synthesis* (vertical axis or 2nd dimension)

My clear focus and synthesis in the regard was predevelopment, developing and pro-urban phases of the studied upazila. The datasets gives an in-depth understanding and dynamic of the changes of land use and land cover between 1951 and 2001.

(3) *Spatial representation* (depth axis or 3rd dimension)

I have presented various visual, descriptive, analytical and statistical approaches in order to show the 3rd dimension of the geographic perspective. Here the basis of the data sources was high resolution satellite images, census data and mauza or field data, which belong to several braches of geography.

In the light of the above perspectives, I have illustrated using the customized matrix of NRC's geographic perspectives in Figure 7-5 how my research fits with their guidelines and played a role to achieve my aim through geography's approach. I can confidently pronounce that my research will help to enhance geographic perspectives and epistemologies and will strengthen the study of geography in Bangladesh and beyond in a distinctive but coherent and integrated way.



Source: modified and redrawn based on NRC, 1997

Figure 7-5: Geography's way of looking at the studied upazila – through its focus on place and resolution (horizontal axis: 1st dimension) cut across the three domains of synthesis (vertical axis: 2nd dimension) which includes phases of land transformation between 1951 and 2001. Spatial representation (depth axis: 3rd dimension) of several branches of geographic data have been used for visualisation and mapping using GIS and image processing approaches.

Glossary of Abbreviations, Acronyms and Local Bangla Terms

The following terms have been widely referred to in the research and need to be explained. The meaning of some local terms varies from region to region but the broad sense remains the same.

Aman: Rice varieties growing in the monsoon season and harvested in November-December.

Aus: Rice varieties growing in the pre monsoon season and harvested in June-July.

Bansh-jhars: Bamboo bushes or forest planted by inhabitants. The *bansh-jhar* are increasing in Savar upazila, e.g. Yearpur union is a good example.

Bazaar: Generally the word *bazaar* used in the area as regular whole and retail business place in rural Bangladesh. There are permanent structures linked with either or both river and road connections. In the *bazaar* all sorts of regular essential goods are available and the rates are generally fixed. See also *haat.*

Beel/Haor: It is a natural lake, usually in the centre of a basin or an abandoned part of a former river channel or deepest part of bydes where water logging is permanent.

Beel: In Savar, a *beel* is the deepest part of a *byde* and holds water throughout the year. *Beels* are a source of water for irrigation and drinking. e.g. *Bilbaghil* in Pathalia *Union.*

Boro: Boro is the name of the most popular dry season rice in Bangladesh. In the study area, boro indicates the land i.e. *boro-jomi* means the land suitable for boro paddy mainly in a byde and occasionally boro season means, November to February, the rabi period. Sometimes *boro-jomi* is used for a type of land synonymous with *byde* land.

Byde/Naama: Low land and subject regular annual floods. It is flooded for several months.

Byde: Elongated winding medium high and medium lowlands of which the wider end is connected to rivers or chwak or chars or beels and all of the other sides are enclosed with Chalas or by its narrow wings. Bydes are very suitable for rabi-crops. The broader end is linked with lowland while the higher relatively narrow end gradually fades into chala lands. Bydes dissect the chala land with their main channels and smaller wings and the rainwater drains through this route and in reverse the flood water enters through the byde.

Chala: Highlands dissected by *Bydes* and also a part of the Pleistocene terrace. The north of Savar is mostly covered by *chala* lands. The chala land is a flood-free region and used to be covered by a belt of shaal forest in the past.

Chars or Naaljomi: Usually means, any accretion of sediment in a river. Here, it is used only for islets in or around the rivers. These accretions are, however, very rarely permanent, for courses of rivers in low alluvial plains are very liable to shift across the flood plain. It may be cultivable in winter. The south-eastern part of the study is comprised mainly this type of char land. The char land may be raised from the river sediments and it is highly vulnerable to riverbank erosion or by the shifting or river channels. During the wet season, the land goes under deep water for several months. The entire southern-most part of Savar *upazila* is covered by it. It is very distinctive from Chwak. Sandy soils make this land type very bright on satellite images. Sometimes local names contain this land class as a prefix or suffix, e.g. Chunar Char of Bhakurta Union. Stable *chars* are also known as *naaljomi.*

Chwak: Lowlands surrounded by greater *chalas* or highland. E.g. Turag basin and Chwak Basaid *mauza* of Asulia Union.

Deghoir: An abandoned river course converted into a natural lake by trapping water during the rainy season. The abandoned channel may be enclosed at both ends by *chars.* It is a perennial source of water for the surrounding area.

Dhaka-Aricha Highway: One of the main national highways in Bangladesh that crosses Savar *upazila.* Its construction, one of the most significant incidents in Savar since the 1960s, has triggered massive change and developments of the landscape therefore easily visible from the sky. In the 1960s, it was a single lane *katcha* road with several gaps (no bridges) on the rivers. Ferry services helped to complete the road. In the 1970s, it was upgraded to a single lane *pucca* road and connected with bridges. The road was widened to two lanes in the 1980s and lastly in the 1990s it has been promoted to a four lane national highway and connected with other national and regional highways within Savar thana.

Dia: A *dia* is an isolated village type in Savar *upazila* surrounded by *chwaks* and located on a *char* like isolated *chalas.* The main economy is related to its surrounding *chwaks.* For example, Kaudia and Ghughudia.

Doba (in Ganda): A *doba* is an oval shaped water body located by the line of a *khal.* It is detached from the *khal* in the dry season. *Dobas* are also surrounded by medium low/high land and used for irrigating *rabi* crops.

***EPZ Dhaka-*2**: Export Processing Zone of Dhaka, the 2nd EPZ established in Bangladesh in the early 1990s and fully operational in the late 1990s at Ganakbari Mauza of Dhamsona Union of Savar. The extension of the EPZ is almost in its final phase. The area is now locally named as *Raptani.*

Eyeel: Normally a rectangular boundary of an agricultural plot bounded by the one foot high mud and clay banks to protect the land from the leakage of irrigated water and topsoil erosion, to mask an ownership boundary, and to use as a footpath to visit other plots. From space and on air photos, a plot may be visible due to its *eyeel.*

Fausholi-jomi: Any land suitable for seasonal crops, mainly for rice, wheat, jute and sugarcane.

Gaon: A *gaon* is a type of village, located on Chala and its economy is based on *chalas* and *bydes.* Examples of gaons are in Chandgaon and Charigaon *mauzas.*

Geocode: The geocode number refers to the geographic area code number as a digital expression of administrative units for recording statistical data with reference to spatial areas. It is in fact a unique numerical address of a geographic area from district level to mauza/village/mahallah level. The first step towards developing a geocode is to prepare a list of all administrative areas and their sub-divisions in order to the administrative hierarchy. The sequence of this arrangement may be done in several ways. The BBS has arranged alphabetically all the areas within each hierarchy and then assigned codes to them. This standard geographic area coding system has been developed with a view to identify the area uniquely and integrate various data series pertaining to a given area i.e. up to mauza level. In this report mauza data have been recorded on the basis of this geocode in a GIS.

Ghash-khila: Pastureland is locally known in Savar as *ghash-khila*.

Graam: Graam means Village. A village must be populated and a few paras combine to make a village. A village has no official boundaries in Bangladesh, but, the number of villages is increasing in general (or in rare cases, as an example, decreases due to river bank erosion). The unofficial boundaries of a village may expand with the increase of population growth. In general, one or more villages comprise a mauza. Normally, cultural and social interactions are focused at the village level.

Haat: Rural periodic market (in general twice a week) in the rural area. This is an open place for selling and buying goods. A *haat* generally sits twice a week. The rate of any commodity fluctuates frequently. Wholesaling is the main attraction of *haats* though there is also retail business. This is also a weekly informal congregation place for the local and nearby communities. Savar *bazaar* is the biggest and oldest *haat* in the region, and sits every Saturday and Tuesday. In the morning a *haat* is busier than in the afternoon. See also *bazaar.*

High land: The land which is above normal flood level. Such lands are divided into two subclasses i.e. moderately well drained highland; where water cannot be retained on land surface with field bounds for more than 1-2 days; and imperfectly drained highland where water can be retained on the land surface within the bounds. Impermeable soils, or soils which can be made impermeable by puddling, may be suitable for transported *aus* and or *aman* paddy if bunds are made to retain rain or irrigated water on the fields.

Household: A household means a group of persons normally living together and eating in one mess (i.e. with common arrangement of cooking) with their dependants, relatives, and servants. This may be a one person or a multi-person household. In other words, when a group of persons living together generally maintain family or family-like relations and take meals from the same kitchen it is termed a household. Popularly, it is described as 'khana'. In some cases in Bangladesh there may be more than one household in a single house or in one dwelling arrangement. Similarly, a household may have more than house or structure or sheds.

HYV Rice: High Yielding Variety of several crops, like rice.

J.L. No: The J.L Number refers to the Jurisdiction List number numerically identifying Mauzas for cadastral, revenue and administrative purposes within a thana or uapzila. The published maps of LGED use these this J.L. codes for the base map of each thana.

Jamindar: The native landlord in the British period, appointed by the then governor. After the independence from the British empire in 1947, the then East Pakistan government eliminated the *jamindar* system. *Jamindars* were responsible for collecting revenues and taxes from the local people (known as *proja*) at that time. The land was under the control of the *jamindars*. Shree Adhar Chandra was the last *jamindar* in Savar. In the early 1950s, the land was distributed to the local people permanently except for some *khas* lands.

Kanda and Kandi: The land intermingled with river cut offs, scours, swales, long and narrow natural levées are known as *kanda*. In general, the land itself indicates *kanda* while *kandi* indicates a village situated on a *kanda* e.g., Kandi Baliarpur of Tetuljhora *Union*.

Katcha (Road): Katcha means a raw format or any feature that is not made of bricks or concretes. Ordinary earthen roads in the village area maintained by local authorities. Generally this refers to 5-8 metres wide unmetalled rural roads suitable only for bullock-carts. In the rainy season, it is not suitable even for cart movement due to the deep mud. Before the late 1970s, *katcha* road were the only transport media. Due to unsuitability in wet periods, the rural areas were very close to water-bodies and the waterways were better communication media at that time. Most villagers preferred to use boats for commodity and people movements. Still the villagers depend on *katcha* roads if there are no *pucca* roads. *Katcha* roads are highly exposed and visible in any season from space in comparison to *pucca* roads. The term katcha is also used for non-cement made house (e.g. katcha Bari).

Kathal (Kathal-bagan or Kathalisation or Jackfruit orchards): *Kathal-bagan* is an orchard having a series of rows and columns of Jackfruit or *kathal* trees. '*Kathalisation*' is the process of planting *kathal* trees after deforesting *shaal* forest on *chala* lands.

Khal: A tributary of the river. Only navigable in the wet season and in dry season used for cultivation. Normally *khals* are *khas* land but the local influential people occupy it illegally by suggesting that the *khal* no longer exists. This is how a *khal* gradually disappears from the map by infilling and ultimately converting with heavy construction or housing. This narrow stream (generally 10-30 metres wide) generally becomes dry during the winter seasons.

Kharif: Term applied to crops grown in the monsoon (April-September) season.

Khas Land: The ultimate owner is the government but it is distributed to the local people on a temporary basis. *Beels*, forested area, unrecorded new *chars* and unused government property are examples of *khas* land.

Land Types: Land levels in relation to seasonal normal flooding have generated 5 grades of depth of flooding. These grades have generally and conveniently become known as land types. Traditionally, the farmers of Bangladesh have from time immemorial sorted out cultivable lands based on single criterion of the depth of normal flooding in rainy season. The name *uchu* (high) and *nichu* (low) are reflective level or depth of flooding. For example, land that is not flooded in normal flood season is highland. Dry crops such as sugarcane, banana and fruit trees thrive in such land.

Mahalla: The smallest identifiable area of a paurashava (municipality) is known to the inhabitants as a mahalla. For statistical purposes mahallas are delineated within wards.

Market: The word usually indicates a modern or *pucca* shopping complex. Generally it is open for 6 days a week.

Mauza: A revenue village with a jurisdiction list number and a defined area is called a mauza. It may be populated or depopulated. The term mauza has also been used as mahallas in the paurashava area. A *mauza* has an officially recognised perimeter. The term is sometimes synonymous with the word *graam*. But the basic difference is that the mauza boundary and numbers in an *upazila* or *thana* are fixed. The *mauza* is a basic revenue collection unit in Bangladesh. A *mauza* consists of a number of plots defined by the *daag* IDs. Each mauza also has a Jurisdiction List (J.L.) number. A *mauza* may be populated or not populated. In Bangladesh and the Indian subcontinent, *mauzas* are widely used also for land records and ownership. The *mauza* maps were first prepared during the 1910s, known as the Cadastral Survey (C.S. or *Sabek*). In the 1960s another *mauza* survey is known as either the Revenue Survey (R.S. or *Haal*) or the State Acquisition (S.A. *Haal*). The scale is 16 inches to one mile. The mauza has been the lowest population census unit in Bangladesh since the 1890s. In the

1990s, for the last time, mauza maps were updated but they have not been officially published yet. The number of plots increases or varies per *mauza* in each updating. See also *graam* or village.

Medium Highland: It is normally flooded up to about 90 cm highland depth.

Para: Para is the smallest unit of a village. Several *paras* make a village. The closest English word would be hamlet. *Paras* may be physically detached and the members of a para are very close to each other, in most cases having blood relations and they are interdependent in so many ways. If a para is big enough, then it may also be recognised as a village or even as a *mauza*, e.g. Panpara.

Paurashava: The area under the jurisdiction of local municipal authority, which has a very limited resource and power to offer its inhabitants. The *paurashava* cannot be termed an urban area directly as it cannot provide basic utility services like running water for its inhabitants, although, definitely, it is not a rural area by definition. However, a *paurashava* can be seen as transitional between rural and urban environments.

Pucca (Road): Anything made of brick or concretes referred to as pucca in Bangladesh. Roads having cement, concrete or bituminous surface and metalled roads/structure. For example, pucca road, pucca footpath, pucca roof, pucca market. The term pucca is also used for a cement made house (e.g. Pucca Bari).

Rabi: The term applied to crops grown and maturing the during dry (Oct.-March) season.

RAJUK: The RAJUK is the highest level statutory Metropolitan City Development Authority under the Ministry of Works. The Town Improvement Act, 1952 gave power to RAJUK to plan, build and take legal action against unauthorised land use and contravention of building construction regulations in the areas under its jurisdiction. Before 1987 it was known as the DIT (Dhaka Improvement Trust) but now it is known as the RAJUK (Rajdhani Unnayan Kartipakhkhya).

Ridge: The term used for the relatively higher parts of floodplain landscape.

Sarobar: An artificially developed *byde* made into a perennial lake or pond. The purpose of converting the lake is to farm fish and to enhance scenic beauty. It also helps to raise the groundwater table during the dry season. A significant variety of migratory bird flocks come to Savar's *sarobars* from Siberia to spend their winter time here for three to four months.

Semi-pucca (Road): Brick made semi-permanent road/structure.

Shaal-baan or Shaal Forest: The scientific name of the *shaal* tree is 'Shorea Robusta'. The vast *chala* land of Savar was under *shaal* forest until the mid 20th century. *Shaal* was the earliest vegetation of this region and was enriched by a unique ecology. Since the 1950s, the deforestation of *shaal* has left only a few square km forest in Savar. *Kathalisation* was the primary step of *shaal* disappearance.

Shapla-Jheels: A special kind of local water lily growing in a lake or *jheel*. The *Shapla* (*nympoea nouchali*) is the national flower symbol/emblem of Bangladesh.

Tek: Highlands surrounded by Chwaks or lowlands, mostly occupied by settlements known as *tek*. They are free from seasonal flooding. Most of the *teks* are located around the eastern border of Savar *upazila*. *Tek* and *Chalas* are the same group of land types. A *tek* is relatively small in size and a detached part *chala* due to a geological fault-line cutting it off from the main landmass. E.g. Sirajer Tek of Biralia Union or Decreer Tek of Pathalia Union.

Tiner Chaal: Roofs of rural or semi-urban settlements made of corrugated iron. The *tiner chaal* in Savar *upazila* has been widely used since the late 1970s. The spectral reflectance of *tiner chaal* is like a bright spot if it is not under the cover of perennial trees.

Union: The Smallest electoral unit of a rural area which is comprised of mauzas and villages is known as a Union. This is the fourth order local government unit and is immediately below the Upazila. A union has an elected union parishad (council). In this study wards have also been mentioned as under the union title.

Upazila: In short, this is a former Police station which has subsequently developed into a revenue /development circle. The boundaries of former thanas are similar to current Upazila boundaries. All Upazila have an Upazila Parishad (Council) which consists of government and local elected representatives. It is also a very important administrative hierarchy for policy makers. The head of an upazila is an elected upazila chairman. It is the third order (below the division and district) local government unit in Bangladesh. In general, a member of parliament (MP) is also selected by the population of one (or more) thana(s). Thus, the population of Savar Upazila selects an MP during each parliamentary election.

Ward: The Smallest electoral unit of urban area is called a ward. A ward is under a paurashava parishad (municipal council). In the BBS report Unions and wards have been recognised as having the same status in the system of geocodes.

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APPENDIX A: AWARENESS ON RAJUK MASTER PLAN (1995-2015)

As I mentioned in chapter 2, the Rajuk master plan was implemented for the first time in Savar Upazila and theoretically this Master Plan should guide the current and future land transformation of Savar Upazila. In the mean time more than 5 years has elapsed, and I interviewed in detail several elected bodies and government official using Video about the Master Plan (1995-2015) based whether this future land transformation is supposed to go ahead. Here I will give a few examples which will give a picture of the lack of awareness as well as some of the contradictions of the Master Plan. I have presented some quotations from my video interviewing, advertisement and tender notice as follows:

Issue (1) Elected Paurashava Chairman: Mr. Ashraf Uddin Khan Emu

The chairman post is the highest people's representative of Savar Municipality and Mr. Emu has been elected as the first chairman of the Paurashava on December 7, 1994. Previously, he also enjoyed the elected posts of Member of Parliament, Union and Upazila Chairman. His views on Rajuk Master Plan:

> "The Rajuk Planners did not consult and discuss with the public representatives and local people and they did not even send us any maps and guidelines at the local authority level after its implementation. Bureaucracy is the main problem, the power struggle between the ministry and local authority is also a problem. Even the plan (TUDP) made for the Paurashava by the ADB has not been trailed properly with me and with the people living here. Sometimes, as a lower governing body, we cannot protest or protect our rights."

Issue (2) Upazila Nirbahi (Executive) Officer: Mr. Md. Abdul Aziz

A UNO is the highest ranking government official at Upazila level and head of the all local government bodies working in Savar. He is supposed to implement all government orders and gazette notifications including obligation of Rajuk Guidelines: But his opinion is:

> "Savar is a part of Rajuk but it does not have any legal basis and jurisdiction in Savar. We have no relation with Rajuk and practically we are part of Rajuk on paper only. There is no land use policy, so the land owners can do anything on their lands by their own personal choice. There are no legal restrictions. So we do not have anything to do with the activities of Commercial Land Developers in SPZ 17-3. Also, we do not have sufficient power to represent the government."

Issue (3) Upazila LGED Engineer: Mr. Saiful Islam Shahid

The LGED engineer is the highest means of implementation of Government Infrastructural Projects and Guidelines, so he should know about the Strategic Planning Zones of Savar, but his response was:

> "I have no idea on SPZ 17-1, 17-2 and 17-3 of Rajuk Master Plan. We do not have any copy of published reports of the Rajuk Master Plan".

Issue (4) Ashulia Model Town: An Advertisement for Restricted SPZ 17-3 Zone

Private Developers are investing millions of Pounds land development for housing complexes in Savar under the banner of Model Towns (Figure A-1). But SPZ 17-3 of Savar is prohibited by the Rajuk guideline for such activities. I collected a quotation from the newspaper advertisement given by the biggest housing complex in Bangladesh for SPZ 17-3, as they claimed:

> "A very close to the capital city, a well-planned city for the 21st Century: Ashulia Model Town".

Figure A-1: The Ashulia Model Town (AMT) advertises everyday through National and International Dailies and using colourful brochures to attract a wide range of customers, but the plan implementation authorities have ignored these and the illegal layout of the urbanization on the restricted zone of Rajuk SPZ 17-3 for Agriculture and Pisciculture. (Sources: left photo, Field Office of AMT at Ashulia and right plan, Brochure published by the AMT, 2001)

Issue (5) A Rajuk Tender: Detailed Area Plan (DAP) of Block 15

Rajuk is supposed to offer a tender on detailed urban area plans for SPZ 17-1 and 17-2, but they did the opposite, i.e. for SPZ 17-3: "One of the main objectives of the DAP for Block 15 (part of SPZ 17-3) is to provide a basic urban design of good quality".

Issue (6) Third Urban Development Project: A Plan Bypassing Rajuk

Savar Paurashava is a part of SPZ 17-1. Also under the Third Urban Development Project (TUDP), ADB (Asian Development Bank) has invested a substantial amount of money for Paurashava planning and the proposed TUDP plan did not mention anything about the Rajuk Master Plan and even did not follow the instruction of the Rajuk though the TUDP plan was initiated a few months later than the gazette notification of the Rajuk master plan.

Having all the above problems and confusions, I talked to the Chief Town Planner (1992-99) of Rajuk Master Plan (1995-2015), Mr. Md. Shaukot Ali Khan. Under his direction and authority the entire plan was surveyed, formulated and published. I asked about the above 6 issues, he responded respectively:

Issue (1) "The structure plan is a broad guideline for the Paurashava. The SPZ 17-1 should be considered for conservation within the guidelines. The paurashava will enjoy its autonomy under the framework of policy and guidelines prepared by the Rajuk Plan. Rajuk overall and local bodies have responsibility for taking practical measures for implanting the plan."

Issue (2) "The Rajuk Master Plan is a part of Law. It would be illegal then if the upazila administration does not follow the guidelines provided by the DMDP (Dhaka Metropolitan Development Plan). Accountabilities are a problem of the government officials and no-one knows clearly about their responsibilities."

Issue (3) "The LGED should know the functions of the local government. They should ask for the Master Plan."

Issue (4) "The Town Improvement (TI) and Building Construction (BC) Acts require the Master Plan to be taken into account, so Land Developers cannot overlook it. Who told them not to take permission for changing the entire landscape? The Turag low-lying basin plays a role of buffer zone between Savar and Dhaka built up areas. This area should be free from all sorts of infrastructural development; otherwise, the core of Dhaka city and its embankments could face serious damage during the flood times."

Issue (5) "If the caretaker of the Master Plan does not understand and respect the guidelines properly, it is really a regrettable matter. If there is any weakness of Master Plan, they can point it out, but should not bypass it."

Issue (6) "Given the status of the Master Plan the donor agency should also follow that as they also contributed funds for its preparation. They should not obstruct it. Aid agencies should see that and they also participated in funding the Rajuk Master Plan."

Then I discussed to the above problems with the Chairman, Professor Dara Shamsuddin, Urban and Regional Planning Department of Jahangirnagar University. He mainly pointed out the role of the Executive Committee of National Economic Council (ACNEC) of Bangladesh Government:

> "Government has a capacity to integrate the plans. The ACNEC gives the approval of the projects. All big projects come though this process. But the practical implications should also be seen by the government bodies, using the local and national mechanisms."

I asked the Chief Town Planner about the limitation of his plan, he said that, for sure, that the lack of High Resolution Remote Sensing Data and application of GIS were real problems. He could not do that due to time and budget constraints. He added that he could get a lesson from the findings of my research and databases that I was developing.

I have made the above discussion just to give a glimpse of lack of coordination of planning or any matters involving government officials which may trigger local conflict with the government systems.